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final report on

UTILIZING SKYLAB DATA IN ON-GOING RESOURCE MANAGEMENT PROGRAMS

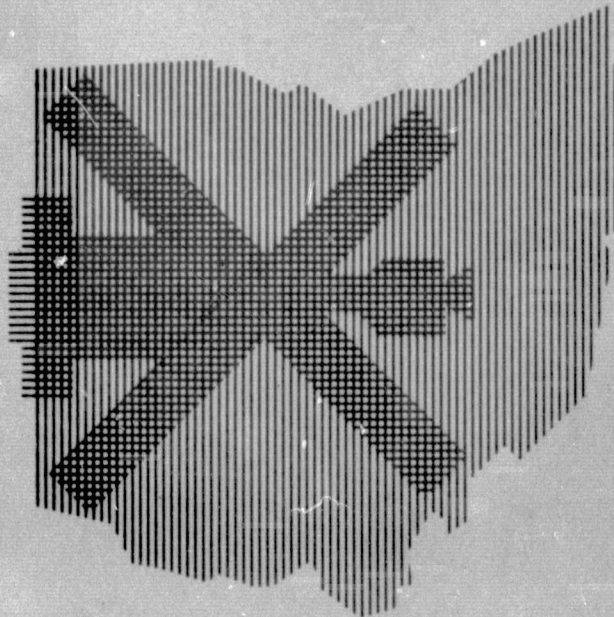
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FINAL REPORT

on

UTILIZING SKYLAB DATA IN ON-GOING
RESOURCE MANAGEMENT PROGRAMS IN THE STATE OF OHIO

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER

November, 1975

OHIO DEPARTMENT OF ECONOMIC AND COMMUNITY DEVELOPMENT

and

BATTELLE COLUMBUS LABORATORIES

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16. Abstract This report summarizes the results of a cooperative NASA State of Ohio program to test the usefulness of Skylab EREP photography in state, regional, and local resource management programs in Ohio. Analysis of Skylab EREP photography performed at Battelle-Columbus Laboratories in the areas of: (1) timber surveys, (2) coal surface mining and reclamation interest, and (3) urban growth-agricultural land encroachment activities are described as are the significance of these results to various participating user agency needs. Timber surveys of a three-county area in Northeastern Ohio included tree species/forest association, tree size, and stand condition. Skylab data and aerial surface mining survey and reclamation analysis studies were used to determine the extent and accuracy that Skylab EREP type data can be used for detecting and monitoring coal surface mining activities and reclamation efforts in Ohio. Techniques for and results of analyzing Skylab photography for determining the extent of urban growth encroachment on prime agricultural land in Central Ohio are presented as are the implications for using Skylab type data for monitoring agricultural land uses for tax assessment purposes. Conclusions regarding the status and plans for routinely using remotely sensed data for resources management activities in Ohio are noted. Lastly, aggregate technical and end user views are provided as to the implications of these results to future NASA Earth resources programs. <p style="text-align: center;">Original photography may be purchased from: EROS Data Center 1001 and Dakota Avenue Sioux Falls, SD 57198</p>					
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FOREWORD

The work described herein was conducted under a cost-share agreement between NASA (Contract NAS3-19521) and a consortium of participating organizations under the leadership of the Ohio Department of Economic and Community Development. The Deputy Director of this Department, Mr. Paul E. Baldrige, served as the program's Principal Investigator.

Most of the technical analysis was performed by, and at, the Battelle Columbus Laboratories. Principal organizations contributing valuable user assessments included the Ohio Department of Natural Resources, Development Department of the City of Columbus, Mid-Ohio Regional Planning Commission, Crossroads Resource Conservation and Development and the Franklin County Auditor's Office.

Mr. John R. Jack of the NASA Lewis Research Center and Mr. Rigdon E. Joosten of the NASA Johnson Space Center served as program technical monitors. Also, valuable assistance was provided by Mr. Ernie Spisz of NASA Lewis Research Center and Mr. Fred Brumbaugh of the Lockheed Support Staff at the Johnson Space Center.

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INTRODUCTION

Background

The State Government of Ohio has been working with NASA since 1972 in programs to evaluate the state-level potential of satellite Earth resources data. The principal types of space platforms being used for collection of Earth resource data are: (1) manned spacecraft, and (2) unmanned satellites. Each type of platform has advantages and disadvantages relative to the problem and approach being taken in each particular resource management program, and as such, the future of Earth resource observation seems to hold a place for both. Data from the LANDSAT series of unmanned satellites are currently being used in State programs, and although the Skylab program is not on-going, it is a prototype to future manned efforts. It is, of course, the significance of these future capabilities that the State of Ohio is interested in assessing.

Whereas most LANDSAT and Skylab investigations have emphasized technical analysis and technique development, this effort concentrated on preparing useful and inexpensive information products based on Skylab data whose significance could be assessed by various types of end users. This particular follow-on program focused on using Skylab Earth Resources Experiment Package (EREP) photography acquired during 1973-74 in three resource areas: (1) timber inventorying, (2) coal surface mining and reclamation, and (3) agricultural/urban land use.

Commercial forest land in Ohio has been steadily increasing since its low point in 1940 and now accounts for over 1/4 of Ohio's total land area. The timber industry has not, however, grown in comparable proportion.

Current state, regional, and local groups are interested in more effectively developing this natural resource. The timber inventory task was designed to evaluate to what extent Skylab type data can be used for: (1) gross inventorying, (2) stand-maturity and species mapping, and (3) condition monitoring as required for comprehensive woodland management operations. Crossroads Resource Conservation and Development Organization (RC&D), a self-help organization formed in 1969 to promote efforts toward natural resource conservation and economic development in three Northeastern Ohio counties, was planning a woodland survey of the total region in connection with developing a woodland management and monitoring plan. The state chose this activity as an opportunity to test the practical end-user value of available Skylab data.

The reclamation of strip mined lands is mandated by Ohio 1972 Strip Mine Legislation. The development of an overall program for reclamation of some 140,000 hectares is only at the initial stage. Accordingly, one of the tasks selected for investigation was the determination of the potential of using Skylab type data for evaluating site conditions and monitoring mined land restoration progress.

The public concern over the preservation of agricultural land, the pattern of expansion of urban areas and the proper uses of Ohio's prime land resources are generating increasing pressure on decision makers to develop and implement better land use plans and controls. The third application task was established to determine if Skylab imagery could be used to quantify and monitor urban development patterns and encroachment on agricultural lands by using the rapidly growing central Ohio region as the test case.

This research project brought together technologists and users in a two-phase data evaluation procedure. The first phase involved data analysis and product generation, and the second phase end-user evaluation of the

significance, accuracy, and operational implications of the products. These two phases had the objective of providing a combined technical/user assessment of the potential operational use of Skylab imagery in a variety of application and user environments. The remainder of this report summarizes the project results.

Program Objectives

The objectives of the program were: (1) to demonstrate how Skylab multispectral photography could be used in on-going resource management programs in the State of Ohio, and (2) to obtain end-user views as to the significance and future operational potential of such demonstrated uses. The latter would include a determination of the institutional mechanism which would be required to link such satellite data to relevant on-going state and local programs operationally.

Scope

The scope of this study involved technical and end user evaluations of the usefulness of multispectral satellite data acquired over Ohio as part of the Skylab Earth Resources Experiment Package (EREP) missions during 1973-1974. Specifically, available imagery from the multispectral camera (S190A) and the Earth terrain camera (S190B) was manually and machine analyzed in relation to three application tasks: (1) timber inventorying, (2) coal surface mining and reclamation, and (3) urban growth/agricultural encroachment. The actual relationship of Skylab imagery coverage to study areas for each application task is shown in Figure 1. In addition, ground observations and appropriate aerial photography were collected by the State of Ohio and Battelle Columbus Laboratories for correlation with the Skylab EREP data.

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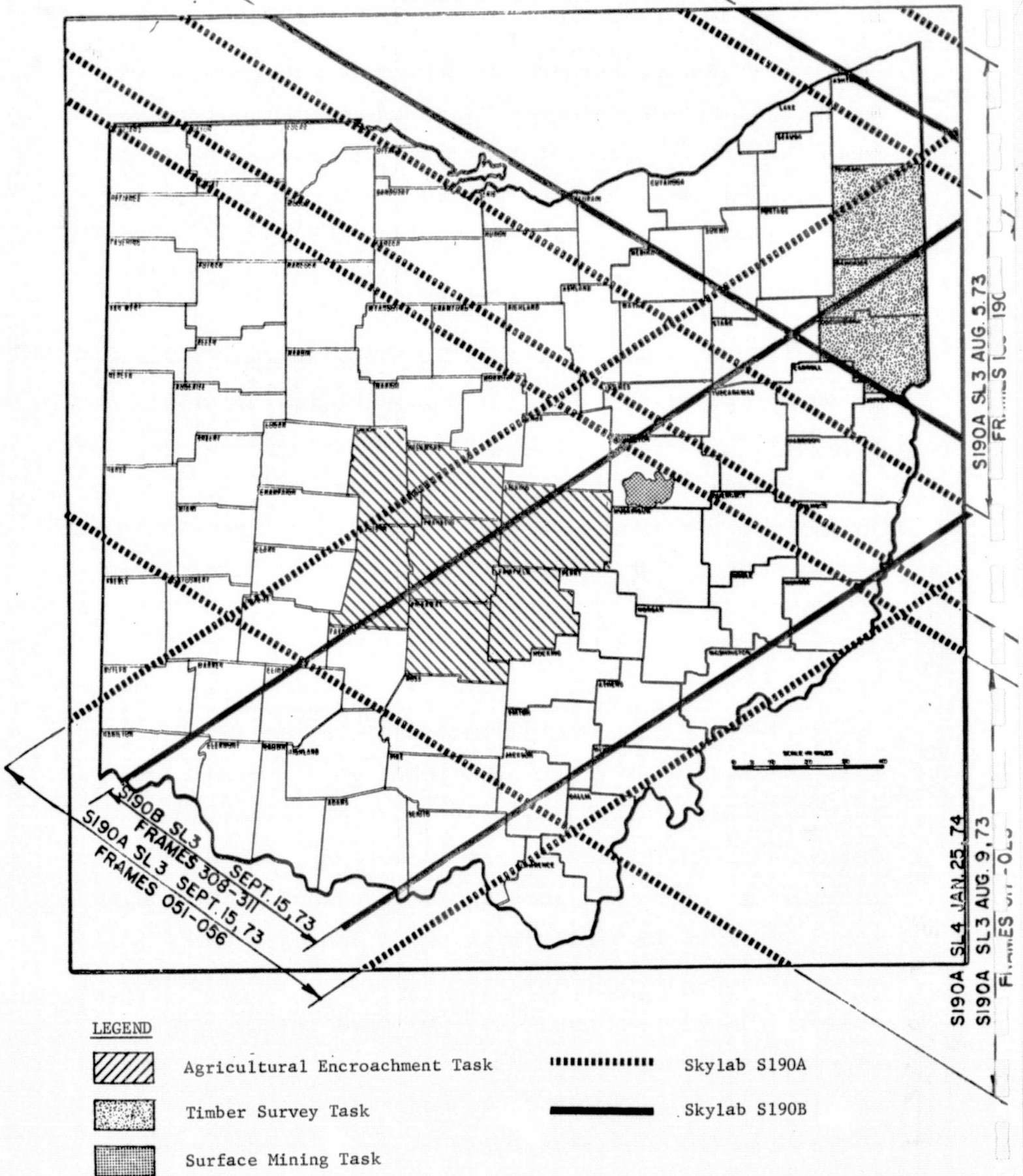


FIGURE 1. TASK STUDY SITES IN RELATION TO SKYLAB 190A AND 190B COVERAGE

The data analysis phase also included the requirement for identifying and generating numerical and map products which could be evaluated by user personnel in relation to their decision-making needs and existing data sources and products.

The three tasks covered different application environments having different resolution, data handling, manipulation, and up-dating requirements. Further, each of these application environments encompassed a different set of users. More specifically the timber inventory task fell within the environment of resource conservation development and encompassed State and local foresters. The mine land reclamation activity was aimed primarily at State-level orphan mine experts and monitors of new mining activity. The agricultural/urban land use task associated with the general application environment of urban planning. This environment encompassed State, regional and local planning agency users.

This diversity in application environments and user requirements had been deliberately built into the program. Thus, the scope of this effort was deliberately broad in terms of including both technical and user activities. In all, six major user organizations were directly involved in evaluating the user potential of the Skylab data analysis findings. These six organizations distributed the products internally, thereby reaching a still broader user audience.

Principal Data Sources

Skylab EREP multispectral (S190A) and terrain (S190B) photography of Ohio acquired during the SL-2, SL-3, and SL-4 missions were used in this study. The film, filter, and resolution characteristics of the multispectral and terrain cameras for each Skylab mission are provided in Tables 1 and 2.

TABLE 1. MULTISPECTRAL CAMERA STATION CHARACTERISTICS AND FILM ROLLS USED ON SKYLAB EREP (S190A)*

Sta	Filter	Filter Bandpass, micrometer	Film Type*	Estimated Ground Resolution††, feet (meters)	Mission & Roll No.		
					SL-2†	SL-3	SL-4
1	CC	0.7 – 0.8	EK 2424 (B&W infrared)	240 – 260 (73 – 79)	01‡, 07, 13	19, 25, 31, 37, 43	49§, 55, 61, 67, 73, A1, 1B
2	DD	0.8 – 0.9	EK 2424 (B&W infrared)	240 – 260 (73 – 79)	02, 08, 14	20, 26, 32, 38, 44	50§, 56, 62, 68, 74, A2, 2B
3	EE	0.5 – 0.88	EK 2443 (color infrared)	240 – 260 (73 – 79)	03, 09, 15	21, 27, 33, 39, 45	51§, 57, 63, 69, 75, A3, 3B
4	FF	0.4 – 0.7	SO-356 (hi-resolution color)	130 – 150 (40 – 46)	04, 10, 16	22, 28, 34, 40, 46	52§, 58, 64, 70, 76, A4, 4B
5	BB	0.6 – 0.7	SO-022 (PANATOMIC-X B&W)	100 – 125 (30 – 38)	05, 11, 17	23, 29, 35, 41, 47	53§, 59, 65, 71, 77, A5, 5B
6	AA	0.5 – 0.6	SO-022 (PANATOMIC-X B&W)	130 – 150 (40 – 46)	06, 12, 18	24, 30, 36, 42, 48	54§, 60, 66, 72, 78, A6, 6B

* Eastman Kodak Company

† SL-1 was the launch of Skylab without crew.

†† At low contrast

‡ Note that all roll numbers are 2-digit numbers. Single-digit numbers were used in other cameras.

§ Without filter

0 Data Used in Ohio Study

TABLE 2. EARTH TERRAIN STATION CHARACTERISTICS AND FILM ROLLS USED ON SKYLAB EREP (S190B)*

Film Type*	Wratten Filter	Filter Bandpass, micrometer	Estimated Ground Resolution††, feet (meters)	Mission & Roll No.		
				SL-2	SL-3	SL-4
SO-242 (hi-resolution color)	none	0.4 – 0.7	70 (21)	81	83, 84, 86, 88	90, 91, 92, 94
EK 3414 (hi-definition B&W)	12†	0.5 – 0.7	55 (17)	82	85	89
EK 3443 (SL-2 & SL-3) (infrared color)	12	0.5 – 0.88	100 (30)	—	87	—
SO-131 (SL-4) (hi-resolution infrared color)	12	0.5 – 0.88	75 (23)	—	—	93

* Eastman Kodak Company

† "Minus blue" filter

†† at low contrast

0 Data Used in Ohio Study

* Source: Skylab Earth Resources Data Catalog NASA/JSC 09016, Houston, Texas 1974.

Roll numbers circled are those containing data used in the Ohio study. A summary of the individual scenes available, area covered, image quality and task relationship are shown in Tables A-1 (S190A) and A-2 (S190B) in Appendix A.

In addition to the satellite and aircraft photography acquired for Ohio during the Skylab program, several existing collections of panchromatic aircraft data were also used in this analysis. The latter included 1962 aerial photography of Franklin County acquired from Ohio Department of Transportation, 1973 aerial photography of selected Ohio watersheds acquired from Ohio Department of Natural Resources (ODNR), and 1972 aerial photography of Northeast Ohio, also from ODNR. This photography was supplemented with low-altitude, color IR coverage of selected sites flown in cooperation with ODNR and Crossroads RC&D during June and July 1975.

Also valuable were ground truth data, base maps and reference material provided by the various participating organizations. These items are referenced in task bibliographies contained in Appendix B.

Research Procedures

General Approach

To accomplish study objectives, technical and user groups were brought together as an application team to develop the specifics of each of the three tasks. Task activities and products were selected to emphasize: (1) the synoptic view obtained from satellite altitudes, and (2) the development of products which end users could assess in terms of operational value. Thus, the application teams had the responsibility for: (1) defining specifics of the analytical approach to be followed and products to be gen-

erated in each task, and (2) assessing the implications of the results when viewed in terms of routine practical use.

Imagery Analyses and Interpretation

Analyses of forested, strip-mined and urban areas were made using two procedures:

- . Photointerpretive analysis
- . Machine-aided analysis

In the first procedure, photointerpreters made decisions and delineated features on the basis of past experience in examining terrestrial features on high altitude aircraft, LANDSAT and Skylab imagery. The second procedure involved the use of specialized equipment which separates, measures, and enhances various film density differences which relate to the natural and cultural features of interest.

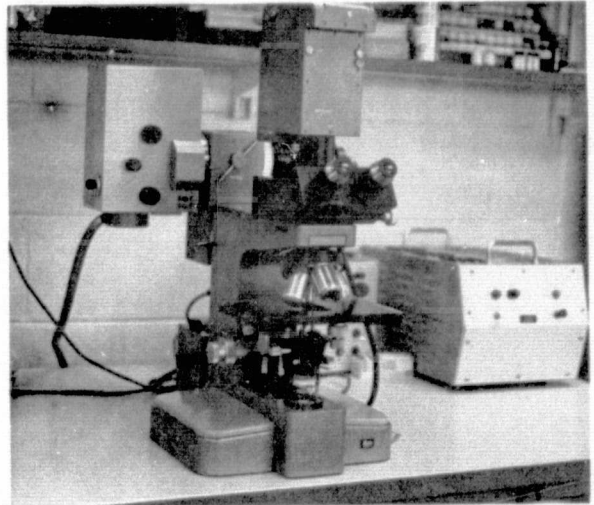
Conventional photointerpretation using optical equipment such as the Richards Multiple Interpretation Module (MIM) (Figure 2a) and the Leitz Orthoplan microscope (Figure 2b) was undertaken to determine: (1) best spectral band(s) for discriminating selected terrain features of concern, and (2) the degree of spatial detail discernible.

The use of high-quality optical equipment was stressed during photo analysis, because the analysis of the satellite data involved photographs as small as 55 by 55 mm, which covered ground areas as large as 28,224 km². This meant that scenes 1 km in diameter on the ground were recorded on film in an area of only 0.3 mm in diameter and features as small as 10 meters by 0.003 mm. The Orthoplan microscope was of particular value, featuring magnification of up to 1000 X with an extremely flat field of view, and a built in 35 mm and 4 x 5 inch camera for recording the image under examination.

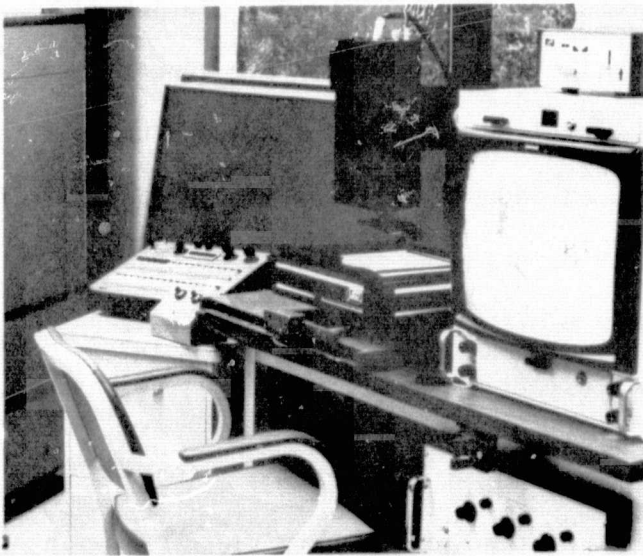
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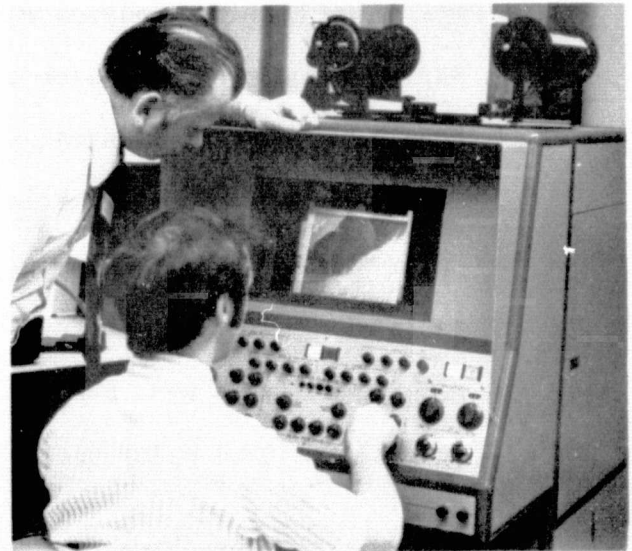
a. Richards Multiple Interpretation Module



b. Leitz Orthoplan Microscope



c. Spatial Data System 703-32
Density Slicing Color System



d. Spectral Data Model 25
Color Additive Viewer

FIGURE 2. IMAGE ANALYSIS EQUIPMENT USED IN BATTELLE'S REMOTE SENSING APPLICATIONS LABORATORY TO ANALYZE SKYLAB EREP PHOTOGRAPHY

Comprehensive inventories of forest, strip-mine and land use features were performed by photographically slicing the imagery and transposing thematic features to large-scale (1" = 1 mile) acetate base maps. These map products, in turn, were reproduced using the inexpensive blueprint/blueline process for distribution to users. The imagery with the best spatial resolution and least density variation was chosen in each survey.

The imagery was analyzed according to the following parameters:

- . Smallest objects discernible
- . Predominant color or tone
- . Distribution and spacing per unit area
- . Predominant alignment.

Machine-Aided Analysis

Machine analyses were performed to determine the correlation of Skylab image tone and color characteristics with actual terrain conditions and to perform total inventories of forest lands, surface mines and urban areas. In addition to the inventories, an indepth analysis was conducted to determine the utility of Skylab data for determining forest maturity, tree species, vegetation stress, surface mine reclamation and land use features. Machine analyses were performed through (a) film density measuring techniques, and (b) additive color viewing.

Density Measuring (Slicing) Analysis. The Spatial Data Video Color System 703-32 (See Figure 2c) was used for quantitatively evaluating the density levels of terrain features as recorded in Skylab multispectral and terrain camera imagery. This equipment measures total film optical densities with the accuracies of a microdensitometer. Microdensitometers typically

measure film densities over small areas 1, 2, or 3 mm in diameter, with a sensitivity as high as .001 D on an overall scale of 4.0 D. The advantage of the 703-32 system is that it measures densities of an entire film frame or any portion thereof at magnifications up to 80 X, projects it on a video screen, color encodes areas of equal density, and calculates areas of equal density.

Density levels as observable in Skylab imagery were a function of the way sunlight was reflected from natural and cultural features and recorded on the photographic film. Bare soil, for example under certain conditions, reflected much of the visible light striking its surface. Forested areas, by contrast absorbed most of the visible sunlight striking its canopy. This resulted in relatively light areas on film (and small density value) wherever the vegetation cover was removed, and dark areas (large density value) where occupied by mature forested stands. Most terrestrial features could not be differentiated as readily as bare and forested areas, having reflectivity characteristics which appeared very close if not overlapping in a given spectral band. For example, brushland and forest land had fairly close density levels and certain forest land and bodies of water could not be differentiated at all within a single spectral band alone. Thus, the ability to identify a given feature by its distinct density difference also determined the accuracy with which it could be mapped and inventoried.

Color Additive Analysis. The Spectral Data Color Additive Viewer (See Figure 2d) was used to examine the multispectral aspects of Skylab imagery. The viewer has four identical optical channels which can be used to simultaneously project up to four multiband or multirate images in registration. Calibrated color filters (red, green, and blue, each having

three intensities) and neutral density filters (20 intensities in steps of .05 D each) can be switched into each optical channel to alter coloration and intensity of the image content of the particular channel. The intent was to accent certain terrain features of priority interest and to depress those of little or no concern.

User Assessments

The products generated from the photointerpretive and machine-aided analyses were distributed simultaneously to six user organizations:

- . Task 1 - Crossroads RC&D and the Ohio Department
of Natural Resources
- . Task 2 - Ohio Department of Natural Resources
- . Task 3 - Ohio Department of Economic and Community
Development, Mid-Ohio Regional Planning
Commission, Franklin County Auditor and the
City of Columbus.

Each organization was provided with a standardized format for developing their evaluations of the projects (see Figure 3). Users were encouraged to circulate the products internally. The evaluations emphasize the relationship of the product to on-going activities, the operational implications inherent in making routine use of the product, the quality of the product in terms of already available material and the cost of using the Skylab generated product when compared with the cost of using presently available materials. Based on the initial evaluations, detailed discussions of the products and the user assessments were conducted.

User Assessment Questions

1. Is the information provided relevant or necessary for your work?
2. Is the information content sufficient to be useful?
3. Do you presently use this or a similar type of information?
4. Is the information in a form (tabular, graphic, proper scale) usable in your present method of doing your work?
5. Could the form or method be changed to make the information more usable?
6. Do you have any operational information system to which this information could routinely be applied?
7. Is the information cost effective, i.e., do you have any cost figures for similar types of data acquisition?
8. Would information such as this be useful updated on a routine basis?
9. How often would you need an information update?
10. Is there a need for information other than that provided which requires repeated and timely updates?
11. Can you make any conclusions or recommendations concerning this effort?

Suggested Format

Brief introduction to user area

Assessment of Information

Relevance/Necessity

Usefulness/Utilization

Cost Effectiveness

Operational Implications

Conclusions and Recommendations

FIGURE 3. USER ASSESSMENT - QUESTIONS AND FORMAT SUGGESTIONS

TASK 1. NORTHEASTERN OHIO TINDER SURVEY

TASK 1. NORTHEASTERN OHIO TIMBER SURVEY

Background

LANDSAT 1 experiments have demonstrated that remotely sensed data from satellites will be of practical value in forestry management. Although efforts to prepare timber type maps from LANDSAT imagery using conventional photointerpretation techniques were largely unsuccessful, computer-assisted methods were successful in proving feasibility.* Also, since Skylab imagery is of considerable better spatial resolution, the potential of using this imagery in the forestry management area took on new promise.

The availability of Skylab data combined with the public and private interests in developing timber resources in Northeastern Ohio motivated this application assessment. The major user organization involved in the task was the Crossroads Resource Conservation and Development Organization (Crossroads RC&D). This organization is working on measures to increase the production of its forestry resources with the cooperative efforts of the following organizations: Ohio Division of Forestry of the Department of Natural Resources; Northeast Ohio Forestry Association, Ashtabula County Industrial Development (Operation Hardwood); Planning Commissions of Ashtabula, Trumbull, Mahoning, and Columbiana Counties; Eastgate Development and Transportation Agency; Cooperative Extension Service of the Ohio State University; Agricultural Stabilization and Conservation Service; Soil Conservation Service through Soil and Water Conservation Districts; Regional Growth Foundation, U. S. Forest Service, Ohio Department of Economic and Community Development; Ohio Edison Company, and local commercial timber operators.

* Earth Resources Satellites - Their Potential in Forestry, G. R. Heath, Journal of Forestry, September, 1974, pp. 573-575.

Objectives and Scope

The basic objective of this Skylab task was to assess the feasibility of using Skylab imagery for assisting in woodland management practices and decision-making. Specifically sought was the extent to which Skylab 190A and 190B photography could be used to inventory the timber resources existing in the three northeastern Ohio counties (Trumbull, Mahoning, and Columbiana). The task was to identify data required for user decision-making, generate appropriate maps and numerical data based on Skylab imagery analysis and obtain end user assessment of the operational implications of the experimental findings.

Research Analysis and Results

Analysis of Skylab imagery of Trumbull, Mahoning, and Columbiana Counties was performed in the following stages:

- . Pre-analysis of all available Skylab imagery to determine its general quality
- . Detailed analysis to determine which single photo channel or combination of channels provided the best spectral and spatial discrimination of woodland areas
- . Mapping and inventory of woodlands (total area) - first level analysis
- . Verification of woodland inventories
- . Analysis of woodland parameters (test areas) - second level analysis

Pre-analysis

A cursory examination of the imagery obtained through seven camera stations (six from the multispectral 190A and one from the 190B Earth terrain

station) over the three county area was initially made to establish the general quality of the available imagery. The best imagery was found to be the photography taken during the SL-3 mission on August 5, 1973. The imagery showed the area to have apparent near ideal atmospheric conditions at that time with less than 1% of the area covered by scattered clouds and cloud shadows. The only exception was the Youngstown, Ohio, area, which appeared covered by a very fine haze originating principally from industrial plants. An area of approximately 500 km² appeared affected representing 12% of the total three county area. The actual scenes or frames examined are identified in Tables A-1 and A-2 contained in Appendix A.

Detailed Analysis

Photoframes in 70 and 230 mm format of the seven photographic stations were examined to determine the station with the best spatial and spectral resolution for delineating woodlands. The experimental analysis established the following order of importance of each of the Skylab data stations for delineating woodlands:

- (1) Earth Terrain Camera, Color - S190B
- (2) Multispectral Camera, Station 3, infrared color - S190A
- (3) Multispectral Camera, Station 4, color - S190A
- (4) Multispectral Camera, Station 5, black and white - S190A
- (5) Multispectral Camera, Station 6, black and white - S190A
- (6) and (7) Multispectral Camera, Stations 1 and 2, infrared black and white - S190A.

Thus, the most useful photographic data for delineating woodlands were those taken by the Earth Terrain Camera and the Multispectral Camera with the infrared color film. Woodlands ranging from fence rows consisting of a single line of trees to areas covering 50 to 100 hectares in the Mosquito and

Meander Creek Reservoir area were examined. Initial analysis was performed with the Zeiss Orthoplan microscope, using magnifications up to 200 times. Larger magnification revealed only useless detail, showing the dye or grain particles in the film emulsions. The best image detail was observed in the imagery which had been enlarged by NASA from the original 70 mm or 115 mm (5-inch) format to a 230 mm (9-inch) format. In this imagery, the grain (in black and white films) or dye (in color films) was far less apparent. In other words, enlargements of the original 70 mm imagery to a larger format proved superior to using a contact print of the original imagery. Tables 1 and 2 show the photographic imagery examined in this process. Combinations of Skylab S190A stations 1, 2, 5, and 6, were also examined on the Spectral Data Color Additive Viewer.

An examination of S190A and S190B hi-resolution (H.R.) color photographs was then performed on the DATACOLOR 703-32 system to determine the uniformity of the imagery due to solar reflection. It was immediately obvious that the S190B imagery was affected by vignetting. This was found to be the case in both the 115 and 230 mm format imagery.* The vignetting effect caused similar forested areas at the edge of the photo to appear darker than those in the center of the photo. When measured on a Macbeth transmission microdensitometer, differences up to .3 D were measured. This meant that forested areas in Trumbull County, located near the edge of the frame, displayed different density from those in Mahoning County locating near the center. Thus, an accurate machine analysis of all three counties simultaneously was not possible. An attempt to reduce the three-county area into

* Vignetting reported to and confirmed by Johnson Space Center personnel. Memorandum JL 12-75-073 Noel Lamar to Rigdon Joosten, October 29, 1975.

smaller $10 \times 10 \text{ km}^2$ sub areas to make machine inventorying possible was also unsuccessful since vignetting still affected the density slicing process. Thus, machine inventory of S190B color data was ruled out since the inventory of even smaller areas was considered too time consuming.

A similar examination of the S190A color infrared imagery revealed a lesser vignetting effect, with the result that areas as much as 50% of each county could be inventoried by density slicing techniques at one time. Machine inventorying was considered an essential part of this task, since manual planimetry of the three-county woodland areas was not practical.

Mapping and Inventory of Woodlands

Maps and inventories of total woodlands were made by delineating all forested areas in the three counties, covering 4193 km^2 . This was accomplished by two methods:

- . Conventional photointerpretation, whereby two experienced photointerpreters delineated wooded areas, using primarily the S190B H.R. color data. The S190A infrared color data was examined simultaneously to corroborate the data seen in the color imagery. To provide a less cluttered image, the S190B color image was density sliced and transferred to Kodak Ektachrome 6115 sheet film. The resulting high contrast copy showed almost exclusively forested areas. Three copies were prepared, each showing one of three counties. The copies were then sandwiched into $100 \times 125 \text{ mm}$ lantern slides. Each of these color images was then rear-projected through a Schneider-Kreutznach lens system (Symmar 1:5.6, $f = 150 \text{ mm}$) onto a $.75 \times .75 \text{ m}$ base map. The base map had been prepared

by contact printing each county from 1:250,000 U.S. Geological Survey topographic maps. Each county had been carefully cut from the map sheets (Geological Survey Index Numbers NK 17-8, Cleveland; NK 17-11, Canton) along its exact boundary. The resulting 1:250,000 ester base negatives from each county were then enlarged 3.95 times to produce the three required base maps on photographic mylar at a scale of 1:63,360 (1 inch = 1 mile).

Prior to the analysis, the interior orientation of the projection elements were aligned until registration and correct magnification of the projected imagery were achieved. Previous measurements on the base map determined that the cartographic quality of the map had been maintained.

Using Skylab imagery of each county, the analysts manually outlined/delineated forested areas as projected onto the base maps (Figure 4). Frequent checks were made by viewing areas of uncertainty through the microscope, on both S190A infrared color and S190B color imagery.

Aircraft and ground truth data were deliberately withheld from the photoanalysts during this process to permit unbiased determinations of the extent to which Skylab data could be used for forest inventories without the aid of ancillary data.

- Machine Inventory. The DATACOLOR 703-32 system was used to inventory the forest areas for the three counties. The inventory provided an accurate total inventory of all forested areas rather than a regression type analysis commonly used in forest inventories involving photo sampling techniques.

TRUMBULL CO. OHIO**INVENTORY OF FOREST LAND FROM SKYLAB PHOTOGRAPHY**

SKYLAB PHOTOGRAPHY
AUGUST 5, 1973
MAP PREPARED
JULY 1975

FIGURE 4. INVENTORY OF FOREST LAND FROM SKYLAB (S190B) PHOTOGRAPHY
 TRUMBULL COUNTY, OHIO ORIGINAL PHOTOGRAPH IN COLOR

(See Attached Blue-line Copy in Appendix C)

The S190A infrared color photography in 230 mm format was used for this task, since it provided a more uniform density pattern than the S190B color imagery of the same area. Although the film was rated to have less than half of the spatial resolution observed in the S190B imagery, this was not a deterrent for total woodland inventory purposes.

The S190A infrared color imagery of each county was initially enlarged (10X) to a scale of 1:250,000 on Kodak 2175 ester base (black and white) copy film. The exact county boundaries were then carefully delineated on the black and white transparency. Finally, each county was overlain with a 10 x 10 km grid. The product was then placed into the DATACOLOR 703-32 system for analysis (Figure 2). The system was adjusted until one 10 x 10 km (up to 16 per county) grid area appeared on the color television monitor magnified to a 1:50,000 scale. At this magnification, woodland areas as small as 2-5 hectares were recognizable, as well as spectral differences which were subsequently analyzed in more detail. Two methods were used to determine the accuracy of the density slice selection by the operators: (1) microscopic examination of fine image detail at the edges of forested areas in the S190A and B color imagery; and (2) superimposition of the data with 1:80,000 aircraft panchromatic photography in areas up to 100 hectares (additional verification procedures will be described later, covering larger areas up to 147 km²). Using a parallel video system with electronic mixing circuitry, the S-190A imagery and the aircraft imagery were superimposed at a common scale. This additional step proved rarely necessary,

since the density slice usually separated forested areas perfectly.

Difficulties encountered were limited to areas covered by clouds, cloud shadows and haze in the Warren-Youngstown area which interfered with the uniform delineation of small woodlands of 5 to 10 hectares. Quadrangle topographic sheets (1:24,000) were also used for gross verification. Comparisons proved, in most cases, that the topographic maps were outdated and differed by 10-15 percent. (See Figures 5 and 6). After color encoding the woodlands in each 10 x 10 km area, the electronic planimeter of the system was used to calculate the forested area. Four calculations were made for each area. Finally the monitor screen with the color encoded image was photographed for documentation. The process was repeated for a total of 48 areas. The numerical results of the machine inventory for each of the three counties are presented in Table 3.

TABLE 3. INVENTORY OF WOODLAND AREAS IN THREE NORTHEASTERN OHIO COUNTIES

County	Total County Area (ha)	Area in County Covered by Woodlands (ha)				
		USDA Survey % (1970)		Skylab Survey % (1973)		Survey Difference (ha)
Trumbull	159,170	39,793	25	54,118	34	14,325
Mahoning	107,502	21,500	20	23,650	22	2,150
Columbiana	138,211	38,699	28	46,991	34	8,292

ha = hectares

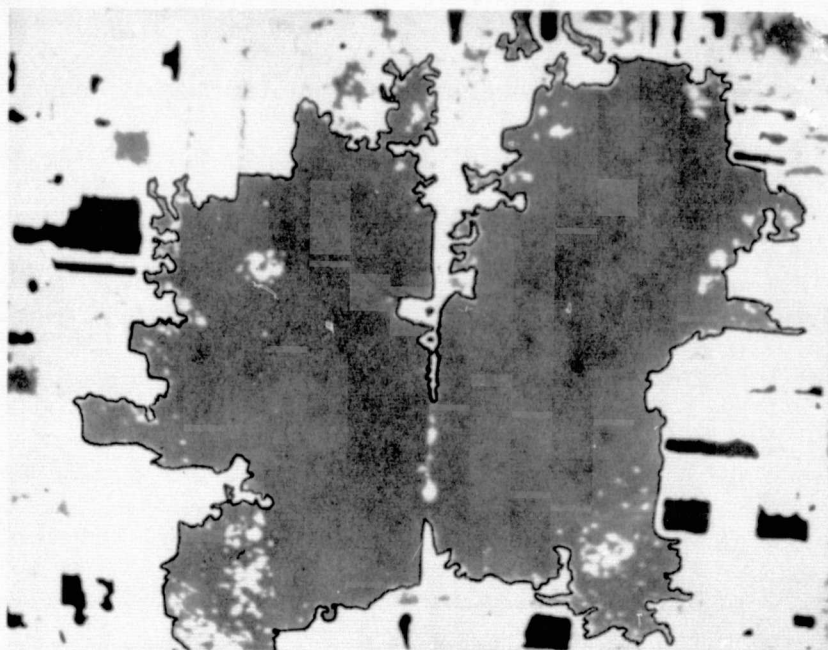


FIGURE 5. COLOR ENHANCED WOODLAND AREA FROM SKYLAB S190B SHOWING EXTENT OF DETAIL DISCERNIBLE (Original scale: 1:950,000 magnified to 1:24,000).

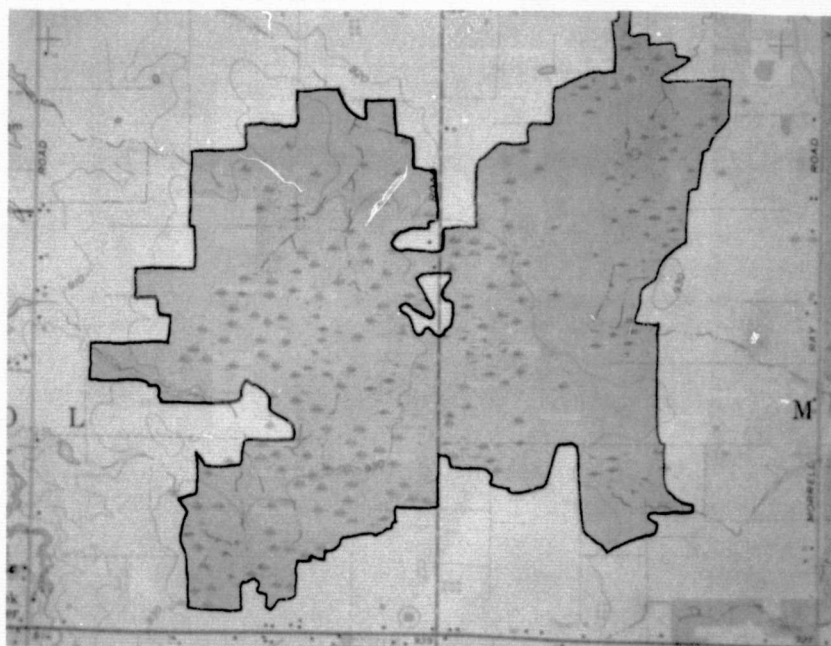


FIGURE 6. SAMPLE WOODLAND AREA ABOVE AS NOTED ON USGS TOPOGRAPHIC MAP SHEET (Original scale: 1:24,000).

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Verification of Mapping and Inventory Accuracies

For gross comparison purposes the Skylab results were compared with a 1970 USDA survey for the same three counties involving photo plot regression estimating procedures.* The results of the USDA survey are also shown in Table 3. In all cases, Skylab results are slightly larger and range from 2% more woodland area in Mahoning County to 9% more in Trumbull County.

To determine the accuracy of the manual mapping and machine inventory of forested areas in the three county area, a comparison of Skylab data results with the Ohio Department of Natural Resources aircraft panchromatic imagery was made. Correlation analysis was performed with a 10.56 x 13.92 km area in Mahoning County (covering one 7.5 minute USGS quadrangle topographic mapsheet (1:24,000)). This was performed by:

Using the Zoon Transfer Scope at the Ohio Department of Natural Resources, the same forested areas delineated in the Skylab and aircraft imagery were transferred to a common base map. The Skylab and aircraft imagery were then manually planimetered. The forested areas in Skylab and aircraft imagery differed by 7.1%. Thus, it could be expected that a total inventory based on aircraft photography would have resulted in a woodland inventory of the three county areas 7.1% larger than determined from Skylab imagery.

With the DATACOLOR 703-32 System, the same quadrangle sized area on Skylab imagery was then planimetered, using the electronic planimeter of the system. This analysis determined

* The Timber Resources of Ohio, USDA Forest Service Resource Bulletin NE-19, 1970, page 122.

a 8.5% difference between the machine inventory of the Skylab S190A infrared color imagery and the aircraft manual planimetry. Thus, forested lands inventoried from Skylab imagery through manual or machine techniques were found to be within 91.5% of inventories made from aircraft data.

Since the forest inventory of the three county areas determined from 2% - 9% higher figures than the USDA inventory (Table 3), it is possible that the actual percentage of forested lands may be an additional 8.5% higher than shown in Table 12.

It is probable, however, that the Skylab imagery provided the superior inventory, since: (a) the analysis was made from color, rather than panchromatic photography, (b) the photo interpreter saw "too much detail" including brushland, which was not included in the forest inventory.

Analysis of Woodland Parameters (Second-Level Analysis)

A second-level analysis of several test sites located within the three county area was performed. The sites were selected by the Crossroads RC&D project staff on the basis that they represented a wide range of woodland parameters of decision-making importance. Among these were:

- . Forest types (types of hardwoods and softwoods)
- . Stand maturity (saw timber, pole timber and seedlings)
- . Brushland (areas of brush, weeds and generally non-commercial grade timber)
- . Condition and Stress (primarily grapevine infestation)

The intent of this phase of the analysis was to determine if the Skylab 190A and 190B imagery provided sufficient spatial and spectral detail to make identification of these parameters possible.

Correlation with the Skylab data and actual ground condition was performed by using small scale panchromatic imagery (1:80,000), and very large scale, oblique infrared color imagery (taken from 600 to 800 meters) over the test areas. Ground truth observation of a hectare site near Mosquito Reservoir was also used. In addition, a detailed vegetation map showing tree types of a 7500 hectare area in Beaver Creek State Park, Columbiana County, recently compiled by ODNR, was also used.

Forest Type Analysis. The known spatial resolution of Skylab data was not expected to provide any reliable means for identifying mixed forest types even under the most favorable atmospheric, lighting and contrast ratio conditions. Species identification usually requires at least 1:15,000 (original) scale imagery. Thus, it was expected from the beginning that information about differences in forest types would have to be derived from the spectral properties of the photographic film, i.e., its tones, densities and/or colors. It was also anticipated that forest differentiation would require a minimum size ground parcel, to record a recognizable image tone on film.

For example, three or four pine trees standing in an oak-hickory forest would provide colors or tones too subtle to be recorded successfully on film by the S190A or B cameras. A hectare of such pines, on the other hand, could possibly provide a tone or color signature of sufficient magnitude to be recognized by the experienced photointerpreter. Furthermore, the ability to recognize any forest type of any size would depend on the spectral properties of the surrounding background or terrain. For example, in the visual bands (.4 - .7 μ m) a forest type standing near a freshly plowed area

would be more easily identified than one standing near water. Water bodies, photographed in the visible portion of the electromagnetic spectrum, frequently record on film tone and/or colors very similar to those for a mature forest.

Photointerpretation. Examination of seven types of Skylab photography showed that the best information regarding forest types in Ohio was provided by infrared color photography. Pine stands, as small as 4-5 hectares, were positively identified in the Meander Creek Reservoir area (Mahoning County).

Photointerpretative analysis of the 190A and 190B imagery made possible classification of the forest types into five types:

Softwood (190A IR color only)

Hardwood (190A and/or 190B)

Mixed (190A IR color only)

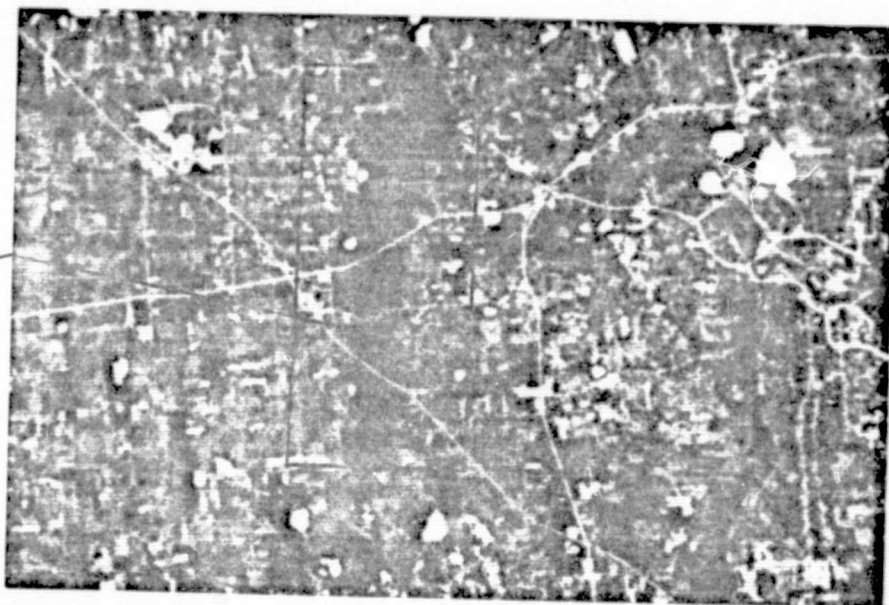
Cut (190A and/or 190B)

Brushland (190A and/or 190B)

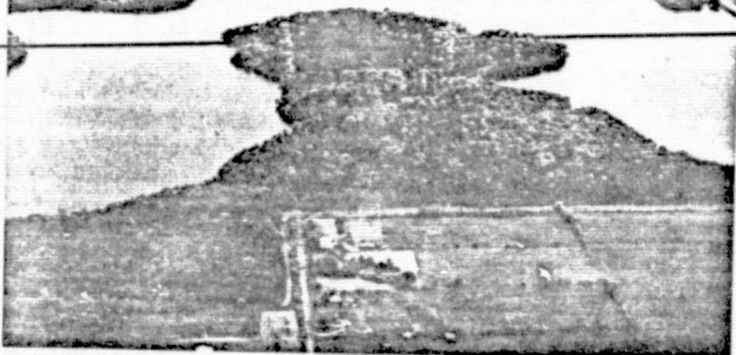
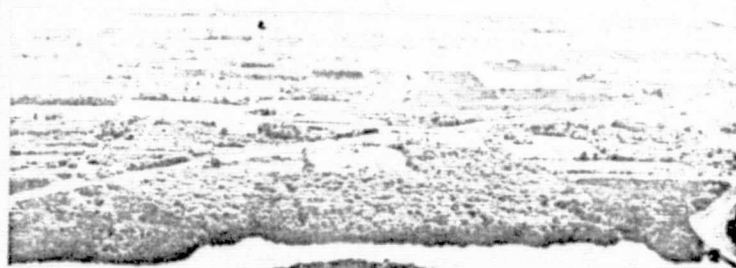
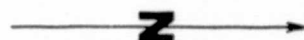
Further differentiation of the mixed hardwood and softwood stands was not possible. This may perhaps be due to two causes: (1) The imagery was taken in August when spectral differences in tree types were relatively small (the ideal time for such photography is usually in May and October in Ohio; and (2) The various types of trees do not occur in parcels large enough to produce a color or tone signature of sufficient magnitude to be detectable on film. The pine trees at the banks of the Meander Creek Reservoir were identifiable because they occur in stands of 4-5 hectares and larger. (See Figure 7).

Color Additive Analysis. Black and white 70 mm imagery of the two visual and the two near infrared bands were examined on the Spectral Data Model 25 Color Additive Viewer at a projected scale of 1:1,000,000. This examination

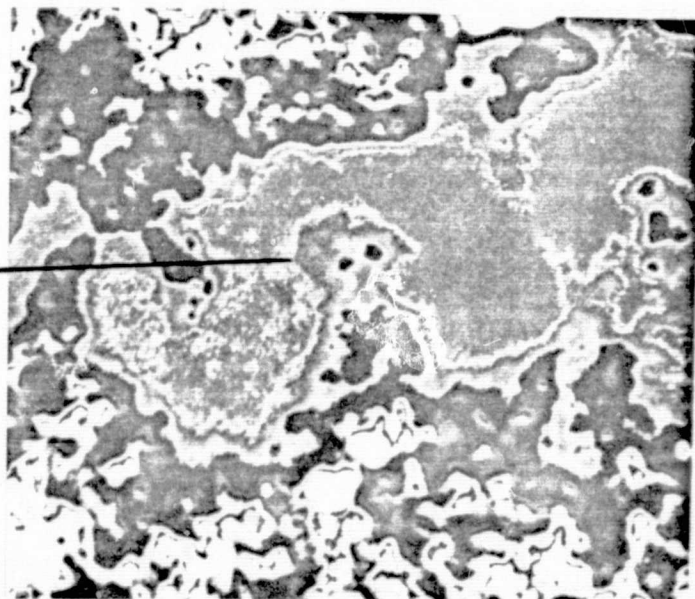
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(a) Infrared Color Photo of Meander Creek Reservoir Area (in box). Dark Red Areas Indicate Mature Pine Stands Adjacent to the Reservoir. Light Red Areas Indicate Hardwood Stands.



(b) Low Level Photo of Peninsula in Meander Creek Reservoir. Dark Areas Indicate Mature Pine Stands. Light Red Areas Covered by Trees Indicate Hardwood Stands.



(c) Image Enhancement of Meander Creek Reservoir Area Shown in Oblique Photo at Left as Encoded on Skylab Imagery. Purple Areas Indicate the Presence of Mature Pine Stands.

did not produce any further useful data. This was primarily due to the relatively small scale of the projected imagery. Future analysis should require magnification of the transparencies to a 1:80,000 scale to permit a projected scale of 1:24,000. This experiment did not provide the time to produce a number of such samples for further analysis.

Machine Analysis. An evaluation of the usefulness of density slicing and "tone signature" analysis for differentiating forest types on Skylab imagery was undertaken.

Density Slicing Techniques. A machine analysis using density slicing techniques was attempted to determine if other than major forest types could be differentiated in the three county areas. While it was known that other Skylab data investigations had reasonable success in identifying forest types, such investigations typically involved relatively large stands of trees, which, because of their size and spectral reflectance characteristics could be reasonably identified and inventoried.

The northeast Ohio area, by contrast, is characterized by mixed woodlands of more than a dozen tone types in small tree stands. To identify and plot these from aircraft photography usually requires color photography taken during May or in the fall when the color contrast and texture foliage appear relatively pronounced.

Using the DATACOLOR 703-32 system density slicing was performed on S190A color infrared imagery showing the Meander Creek Reservoir area where large pine stands could be readily differentiated (Figure 7). A Kodak Filter 25A in front of the video camera of the system was essential.

Using S190B imagery, an area near the Ohio River, the so called "Beaver Creek State Park", was then examined for all three types (oak,

hickory, pine, etc.). This area was chosen, because it was one of few areas where documentation of vegetation types at a large scale was available.

Figures 8 and 9 show that density slicing techniques do provide information about major tree types - associations such as oak, hickory, and pine - provided such analysis is made at scales of 1:24,000 and larger.

Tone-Signature Analysis. A machine analysis was made to determine if the densities of forested areas with certain types of trees could be distinguished by measuring the densities within the image, and by compiling the resulting data into "tone signatures". "Tone signatures" are a means to show the film density distribution of a given terrain feature, recorded on film, similar to the way "spectral signatures" represent the spectral distribution of the actual features on the ground. It is usually shown graphically by plotting percentage of film density (0 - 100%) as a function of density, interval (0 - 4.0D). Tone signatures compiled of forested areas recorded on S190B color film, for example, showed high percentage values at approximately 1.9D, whereas freshly plowed fields display tone signatures which peak at approximately 0.6D. Thus tone signatures are a means to effectively differentiate terrain features recorded on film. Figure 10 shows a sample of tone signatures obtained from color infrared film taken with the S190A multispectral camera. Tone signatures measured on film of an area representing .5 km in diameter on the ground of mixed hardwood stands and predominately softwood stands seem to indicate sufficient spectral difference to make feasible machine processing of the S190A color infrared data for discriminating major forest types. By machine processing is meant here, the digitization of the imagery and subsequent application of computerized techniques.

"Tone signatures" are not to be confused with "spectral signatures" which are measured with a radiometer in the actual scene. While a definite



FIGURE 8. WOODLAND ASSOCIATION ANALYSIS IN BEAVER CREEK STATE PARK, COLUMBIANA COUNTY, OHIO. Red Color Denotes Mixed Hardwoods (Oak Hickory); Green Color Represents Mostly Pines (Red, White and Scotch). [Using S190B] ORIGINAL PHOTOGRAPH IN COLOR

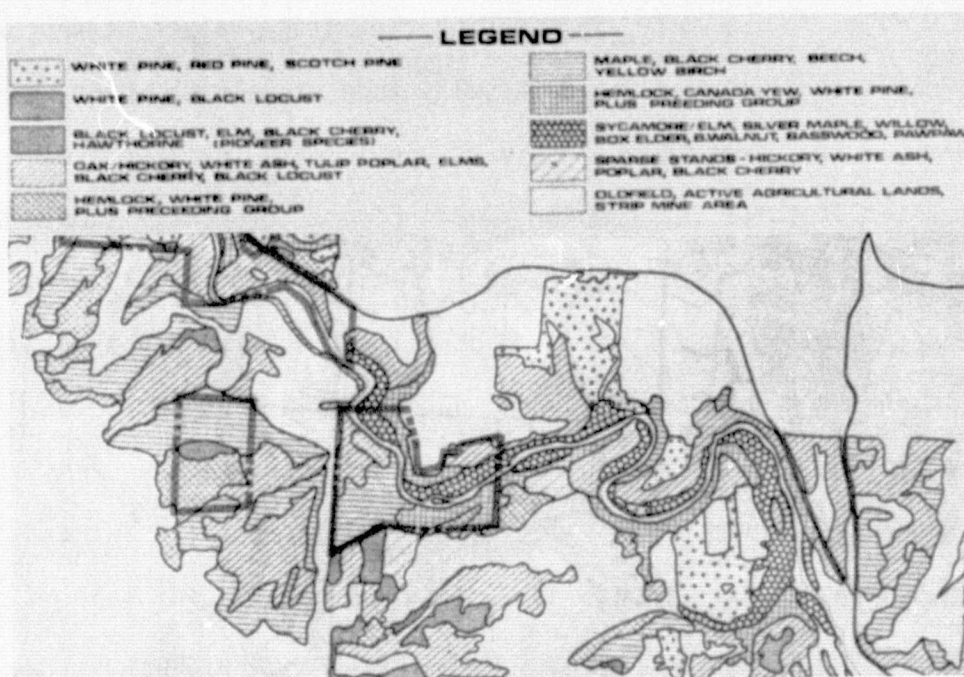


FIGURE 9. PORTION OF BEAVER CREEK STATE PARK VEGETATION MAP
(Courtesy of Ohio Department of Natural Resources)

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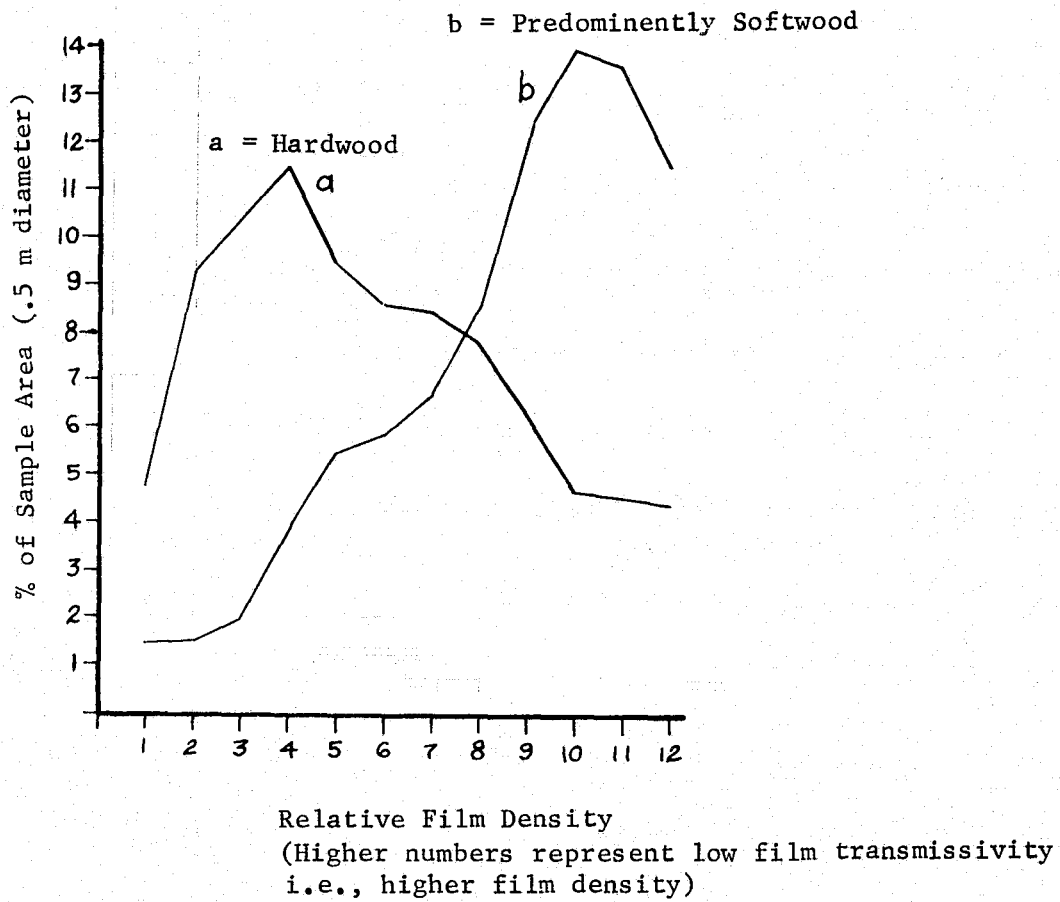


FIGURE 10. "TONE SIGNATURES" OF SAMPLE FORESTED AREA MEASURED ON S190A IMAGERY (a) HARDWOOD STANDS, (b) PREDOMINANTLY PINE STANDS.

relationship between spectral and tone signatures exists, it can never be assumed that forest features appearing in an image will provide the same spectral information as the actual forest on the ground. Measuring on film merely provides information about the way trees record in the dyes or grains making up the film emulsion. Measuring the densities or tones on film, however, can provide image content, not readily observed any other way. Since the infrared color photography was found to contain the most useful information regarding tree types, this photography was enlarged on the DATACOLOR 703 - 32 system until it appeared at a scale of 1:15,000 on the video monitor. To distinguish softwood stands, a Kodak #25 filter had to be placed over the video camera. Each image was sliced into 16 density steps of .05D each. A choice of a larger number of grey levels, applied in earlier experimentation did not provide any additional information. The image was then color encoded, and photographed for documentation. The density content of the image was then measured by using the electronic planimeter of the system and the tone signature compiled.

Stand Maturity

Stand maturity may be derived from aerial photography by measuring tree heights, tree density and crown closure. The purpose of this portion of the analysis was to determine if Skylab photographs could be used to measure one or more of these three parameters. A detailed examination of virtually hundreds of forested lots in Northeast, Central and South Ohio has shown exclusively that the most mature woodlands (tallest trees, dense ground coverage, and dense canopy closures) could be identified by relatively high film density readings.

More simply stated, a forested area with a heavy canopy, with tall trees standing very close together, was always recognizable by very dark tones

or colors in black and white panchromatic or color and color infrared film. Unfortunately, sometimes in the black and white and color film these tones or colors (respectively) appeared similar to bodies of water characterized by certain water depth and water clarity. In the color infrared, of course, tones or colors of forested areas appear quite red, and water blue, making such a distinction on the basis of spectral characteristics readily possible.

By density slicing the color and color infrared film, areas covered by forest could be separated into as many as 32 levels. By examining aircraft data in stereo of 16 sample sites in the three county area, and thorough confirmation by the Crossroads staff, a correlation between stand maturity and the 32 density levels was established. It was found that by reducing the density intervals to 5 levels, the following stages of forest growth could be identified:

- Mature timber

- Intermediate and pole timber

- Seedlings and Saplings

- Brushland

- Cut/Cleared areas.

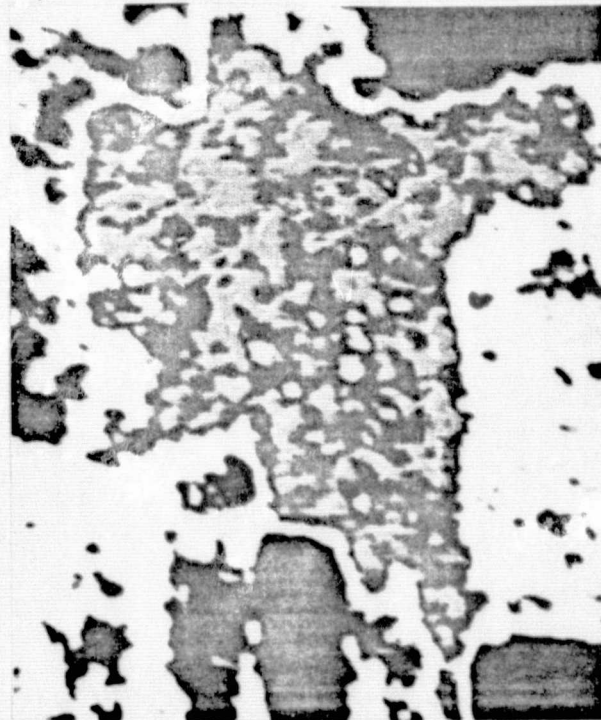
Figure 11 shows these levels of density slicing of a sample area in Mahoning County, Ohio which reflect only three stages of stand maturity. It is one of 16 sample areas in the three county area in which machine determination of stand maturity from Skylab S190B imagery was undertaken. Correlation with forest management personnel from the Crossroads RC&D staff confirmed the validity of the classification based on density slicing techniques.



a. Aircraft Photo of a Woodland Area in Mahoning County, Ohio. The 52 Hectare Area Contains Medium to Small Saw Timber (From Stereo Analysis).



b. S190B Image of Area on Left Shown on Data Color System 703-32 Monitor Screen



c. Image Enhancement of S190B Photo Showing Woodland Area in (a) and (b) above.

Red - medium saw timber
Green - Pole and small saw timber
Blue - Brush and open fields

Condition/Grapevine Stress

In the timber area investigated, grapevine infestation and damage is a major forest management problem. Brief analysis of several areas known to be experiencing serious grapevine-stress infestation was made with no detection success. The damage/stress conditions do show prominently in the low-altitude color infrared photography. The areas affected were apparently too localized to be discerned on the Skylab imagery. Hence, satellite spatial resolution approaching 2-5 meters would be required to monitor such infested areas in Ohio operationally.

User Assessment

Crossroads Resources Conservation and Development

The principal product coming from the Skylab program in Ohio for the inventorying of timber in the northeast has been a map showing the location of forest land 10 acres and over for the three northeast counties of Trumbull, Mahoning and Columbiana. This map provides the location of the timber resource in these counties; however, this information is only partially helpful in the task at hand within Crossroads RC&D.

The Crossroads RC&D is engaged in a woodland program to develop the timber industry in northeastern Ohio. This economic resource is somewhat different than the timber industry in other portions of the country in that the resource is scattered in location and ownership with many degrees of development and intent for productivity. Of interest to Crossroads is not only the location of forest lands but also forest species and maturity. With such information provided on at least an annual basis the Crossroads Woodland

Committee can develop more effectively this valuable resource for the people of this area. A look at the Skylab product in its present form shows where forest lands of a particular stand area may be located, but more far reaching and valuable information such as forest species or association and forest maturity is not available.

More work apparently needs to be done in this area of mixed hardwood stands, although some preliminary output suggests this information may possibly be extracted from Skylab type data.

At this point, the utilization of Skylab type data is of marginal value to the Crossroads RC&D. If the promise of identification of forest species and forest maturity is realized the value and utilization of this data will increase dramatically. Crossroads Woodland Committee and staff agreed the following additional data should be derived to make the Skylab inventory more practical:

- (1) Delineation and acreages of hardwood and softwood stands.
- (2) Delineation and acreages of brush, pole stands and mature timber stands.
- (3) Delineation and acreages of hardwood timber stand types such as oak, hickory, beech, maple, and etc.
- (4) Annual monitoring of timber drain, new plantation and natural regeneration.
- (5) Delineation and acreage of urbanized areas versus open space.

The Ohio Department of Natural Resources

In addition to the Crossroads involvement, the Ohio Department of Natural Resources Planning Services Section assessed the Skylab product and

compared it to information provided by aerial photographic interpretation. Also, by integrating the digitized Skylab product covering Austintown Township with the Ohio Capability Analysis Program (OCAP), the potential to infer information about forest species was evaluated.

Comparison of the two maps (Figures 12 and 13) of Austintown Township indicate that the Skylab results (4500 acres) underestimate the amount of forested area (5000 acres from the OCAP aerial photographic interpretation). It appears that most of this discrepancy represents small tracts or thin corridors of wooded areas that were too small for representation on the 1 inch = 1 mile map originally used. Certainly the outlines of major tracts can be recognized on the two. This is true not only for the areas near the reservoir, but also throughout the township. The ten percent difference corresponded to the accuracy statements made in the technical analyses phase comparing Skylab and aerial results. Where no aerial photography coverage of woodland areas exists Skylab data could provide a valuable input to the data base.

As can be seen from the OCAP vegetation map, there is considerable evergreen woods in the township, which are plantations, largely around the Meander Reservoir at the western boundary of the township. Any forest inventory must distinguish between such evergreen stands and the natural second growth deciduous woods typical of this part of Ohio. The distinction is easily made on aerial photography. Due to problems in the data, forest species identification was difficult and an overall attempt to identify species for the entire counties was not made.

However, there is a relationship between soils and forest types that allows a general estimate of the types of forest species to be expected on a particular soil type. This approach is described in the Mahoning County

AUSTINTOWN FOREST TRACTS FROM SKYLAB



LEGEND

SCALE 1" = 2400'
 CELL WIDTH(FT): 200
 CELL HEIGHT(FT): 250

DATA CODE	MAP SYMBOL	CODE DESCRIPTION	NUMBER OF CELLS	PERCENT OF STUDY AREA	AREA(ACRES)
10	11	WATER FORESTED AREAS	928	6.26	1054.3
		NONFORESTED AREAS	3706	26.92	4502.3
			4792	66.90	11233.3
TOTAL	3		14625	100.00	16789.9

STATE OF OHIO
 DEPARTMENT OF NATURAL RESOURCES
 DIVISION OF PLANNING AND RESEARCH
 08/19/75

FIGURE 12. COMPUTER MAP OF AUSTINTOWN TOWNSHIP, FOREST TRACTS FROM SKYLAB S190B
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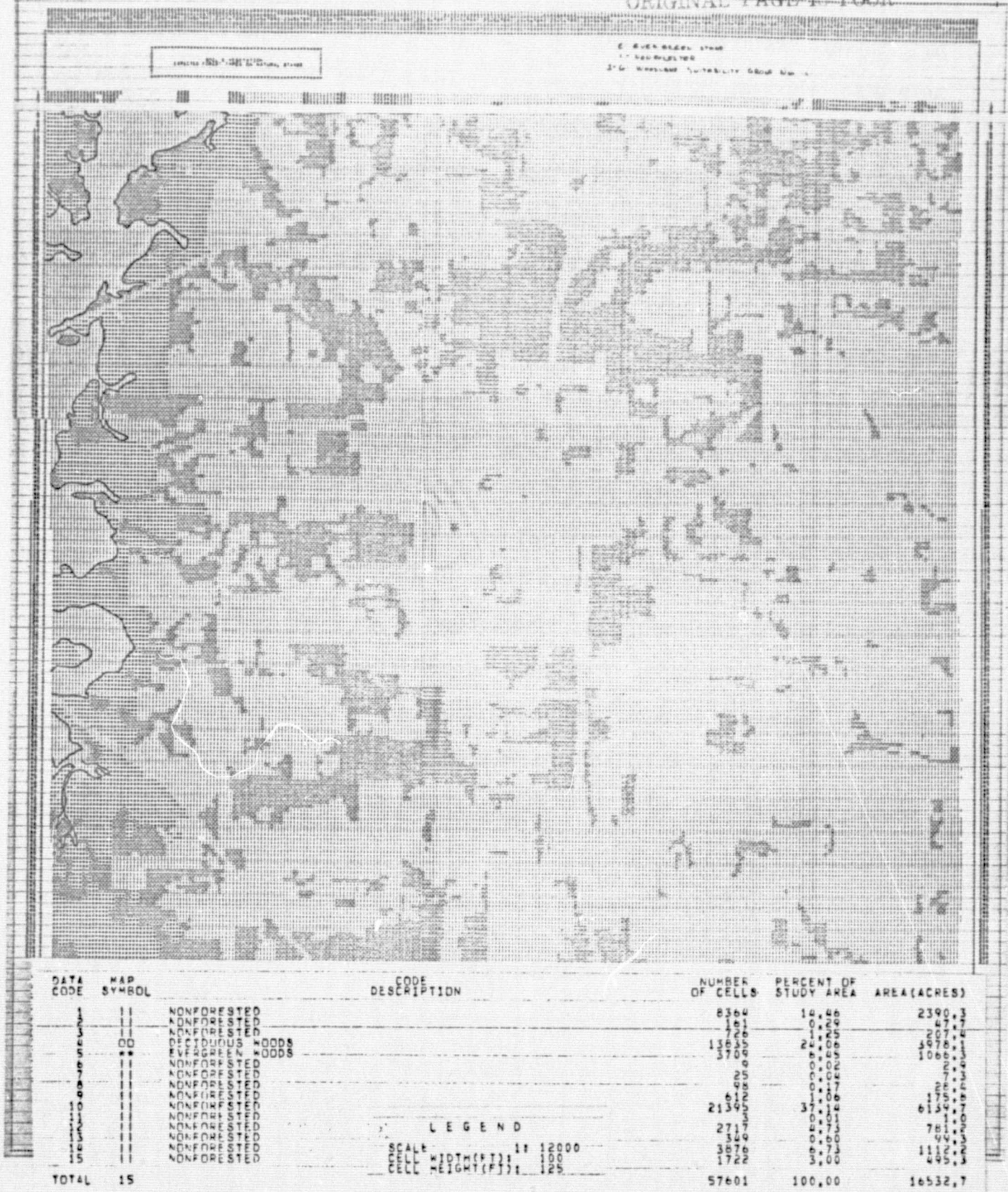


FIGURE 13. COMPUTER MAP SHOWING SOIL AND VEGETATION FOR AUSTINTOWN TOWNSHIP AS INDICATIVE OF WOODLAND SUITABILITY. (From Ohio Capability Analysis Program).

Soil Survey. An attempt to make this correlation using the Austintown Township OCAP files was partially successful. The 3 lines of map data attached to the OCAP vegetation map represent the grouping of the identified forest tract into Woodland Suitability Groups. The numbers used as mapping symbols on this map correspond to the group numbers as described in the soil survey. It should be pointed out the forest species mentioned in these groups are those which will grow well on that particular type of soil, not that they are definitely present in any particular tract. In fact, because they do grow well in a given tract may mean that individuals of the desirable species may have already been cut for timber. There are, however, some inferences which can be drawn from the types of species grouped together that are useful in estimating the type of forest habitat represented by a given tract. If past land use practices for the area are known in general, and if one has a general knowledge of the types of forest associations to be found in an area, this identification and mapping of Woodland Suitability Groups can be useful in inventorying forest resources and in guiding on site investigations; however, in order to utilize the Skylab data in a Woodland Suitability classification scheme, detailed soils data is of course necessary.

TASK 2. COAL SURFACE MINING AND
RECLAMATION STUDY

TASK 2. COAL SURFACE MINING AND RECLAMATION STUDYBackground

Various LANDSAT investigations have experimentally demonstrated that repetitive satellite multispectral data can be used effectively by private and governmental agencies in various coal surface mining and reclamation planning, inventorying and monitoring functions. Still required, however, are follow-up programs aimed at: (1) evaluation and prioritizing data needs and problems; (2) demonstrating how satellite data can be cost-effectively utilized by user agencies (for both old and new strip mined land interests and problems); and (3) documenting the detail and accuracy that specific surface mining and reclamation features can be interpreted.

In response to the 1972 Ohio Strip Mine Law, the Ohio State Legislature created the Board on Unreclaimed Strip Mined Lands to study the extent of and to make recommendations concerning restoration of the State's strip mined lands. An extensive study* followed which included the inventory of all surface mined lands in the 23 Southeastern counties (79 watersheds) affected. The basis for this inventory was 1973 aerial photography the State contracted to be flown over the total area (3000 photographs) and formatted to a scale of 1:24,000. Interpretations of the photography included:

1. Determination of boundaries and acreages for all surface mined lands;
2. Delineation of active surface mines; and
3. Categorization of surface mined lands by type and amount of reclamation required.

* Land Reborn, 1974.

~~PREPARED BY LAND REBORN~~

The aerial photography also resulted in a series of index maps (scale 1:250,000) showing the extent of surface mining in each of the 79 watersheds to aid in future reclamation planning activities. The photography was supplemented by ground truth data on environmental quality. Since the photography flown and the interpretations made were in direct response to user needs for developing and implementing a surface mining reclamation strategy, they become valuable baselines for evaluating the potential utility of Skylab 190A and 190B photography.

Task Objectives and Scope

The objective of this task was to determine to what extent and accuracy Skylab photography can be used to detect coal surface mining and reclamation activities in Ohio.

In line with available time and resources, data analysis efforts were limited to one watershed area. The area was chosen on the basis of the availability of good Skylab coverage and discussions of watershed priorities with the principal participating user agency, the Ohio Department of Natural Resources. The location of the selected watershed is shown on the study site map (Figure 1).

Research Analysis

In this task, the following research procedure was applied:

- . Pre-examination (photointerpretation techniques only),
including watershed selection
- . Detail analysis for delineating specialized surface mine
features in selected sub areas within the watershed
(photointerpretative and machine analysis)

- . Comparison of strip mine features discernible in Skylab and aircraft photography (Land Reborn Analysis)
- . Analysis of data utility for mined land reclamation/restoration programs.

Results

Pre-examination

All available Skylab imagery obtained with the S190A and S190B cameras during the SL-2, SL-3, and SL-4 missions were examined on the Richards Multiple Interpretation Module for five watersheds initially considered. These included the watershed involving Hocking, Athens, Vinton and Meigs Counties, the Southeastern Coshocton County watershed, the Jackson and Gallia Counties watershed, the Noble County watershed, and the Conotton Creek watershed. Since SL-3 (S190A and S190B) photography taken over Coshocton County on September 15, 1973, was of such good quality - zero cloud cover and no observable haze, this watershed was chosen as the study site for detailed surface mining analysis.

Detailed Analysis

A detailed examination of strip mine areas in eastern Ohio showed that strip mine activities resulted in characteristic changes in the original terrain, by which the activity could be identified. It was found that, generally strip mined lands could be classified into four types:

- . Active
- . Orphaned* or abandoned land
- . Areas undergoing reclamation or restoration
- . Reclaimed land (natural and human reclamation).

* In Ohio, defined as unreclaimed land prior to September, 1972.

In each of these four categories, the slope, smoothness of the terrain, the vegetation and hydrological features undergo certain changes which appear quite vivid, and sometimes very subtle. The ability to qualitatively and quantitatively extract pertinent information on critical parameters occurring in strip mined areas was considered to be the key for correctly classifying such areas. The ability to identify, delineate and inventory strip mine lands was considered the prerequisite for providing useful information to state and strip mine operators for managing active areas, restoring orphaned lands, and monitoring reclamation progress.

Photographs from each of the seven Skylab camera stations covering this watershed were examined on the Richards Interpretation Module to determine which specific features could be distinguished in each of the surface mining activity categories above. Magnifications up to 60 times were used. A matrix was compiled in Table 4 showing which Skylab data station made identification of a given strip mine feature possible. The smallest area still identifiable as a strip mine area was also determined.

The six transparencies taken by the S190A camera were examined sequentially to make a qualitative evaluation, if any one channel could provide detail in addition to that discernible by the S190B IR image alone. This included an attempt to evaluate the imagery for possible stereo viewing. It was found that the stereo parallax of the S190A imagery was only sufficient to detect relief in hilly areas of about 200 meters. This was not enough to delineate strip mine detail.

A novel way to produce stereo viewing with the S190B data was found, however, by viewing the imagery in conjunction with frames of high altitude aircraft photography. A single frame of the S190B color IR was enlarged to a scale of 1:80,000, the same scale at which the panchromatic photography

TABLE 4. USEFULNESS OF SKYLAB 190A and 190B PHOTOGRAPHY FOR IDENTIFYING STRIP MINE FEATURES

		High ←		Usefulness				→ Low	
		S190B		S190A					
	Wavelength	IR Color (.5-.88 μm)	Color* (.4-.7 μm)	Color (.4-.7 μm)	Color IR (.5-.88 μm)	B&W (.6-.7 μm)	B&W (.5-.6 μm)	B&W IR (.7-.8 μm)	B&W IR (.8-.9 μm)
Feature	Estimated Ground Resolution	30 m	21 m	40-46 m	73-79 m	30-38 m	40-46 m	73-79 m	73-79 m
1. Active Strip Mine Land									
1.1 Lack of Vegetation		Yes		Yes	Yes	Yes	Yes	Marginally	Marginally
1.2 Strip Mine Highwalls		Yes		Yes	Yes	Yes	Yes	No	No
1.3 Slope (recognized by rough terrain texture)		Yes		Yes	Yes	Yes	Yes	No	No
1.4 Coal Seam		Yes		No	No	No	No	No	No
1.5 Equipment		No		No	No	No	No	No	No
1.6 Spoil Banks		Yes		Yes	Yes	Yes	Yes	No	No
1.7 Access Roads		Yes		Yes	Yes	Yes	Yes	No	No
2. Orphaned Strip Mine Land									
2.1 No or Sparse Vegetation		Yes		Yes	Yes	Yes	Yes	No	No
2.2 Highwalls		Yes		Yes	Yes	Yes	Yes	No	No
2.3 Spoil Banks		Yes		No	No	No	No	No	No
2.4 Impoundments		Yes		Yes (1)	Yes (1)	No	No	Yes	Yes
2.5 Impoundment Quality		No		No	No	No	No	No	No
2.6 Access Roads		Yes		Yes	Yes	Yes	Yes	No	No
3. Areas Undergoing Reclamation									
3.1 Equipment		No		No	No	No	No	No	No
3.2 Smooth Slopes		Yes		Yes	Yes	No	No	No	No
3.3 Vegetation 0-40% Coverage		Yes		No	Yes	No	No	No	No
3.4 Vegetation 40-80% Coverage		Yes		Yes	Yes	Yes	Yes	Marginally	Marginally
3.5 Vegetation 80-100% Coverage		Yes		Yes	Yes	Yes	Yes	Yes	Yes
3.6 Impoundments		Yes		Yes (1)	No (1)	No	No (1)	Yes	Yes
3.7 Impoundment Quality		No		No	No	No	No	No	No
3.8 Access Roads		Yes		Yes	Yes	Yes	Yes	No	No
4. Reclaimed Strip Mine Areas									
4.1 Vegetation 40-80%		Yes		Yes	Yes	Yes	Yes	Yes	Yes
4.2 Vegetation 80-100%		Yes		Yes (1)	Yes (1)	No	No	Yes	Yes
4.3 Impoundments		Yes		No	No	No	No	No	No
4.4 Impoundment Quality		No		No	No	No	No	No	No
4.5 Access Roads in Present Use		Yes		Yes	Yes	Yes	Yes	No	No

* S190B Color not available for study site areas.

(1) If several hectares in area.

 μ m Micrometers

m Meters

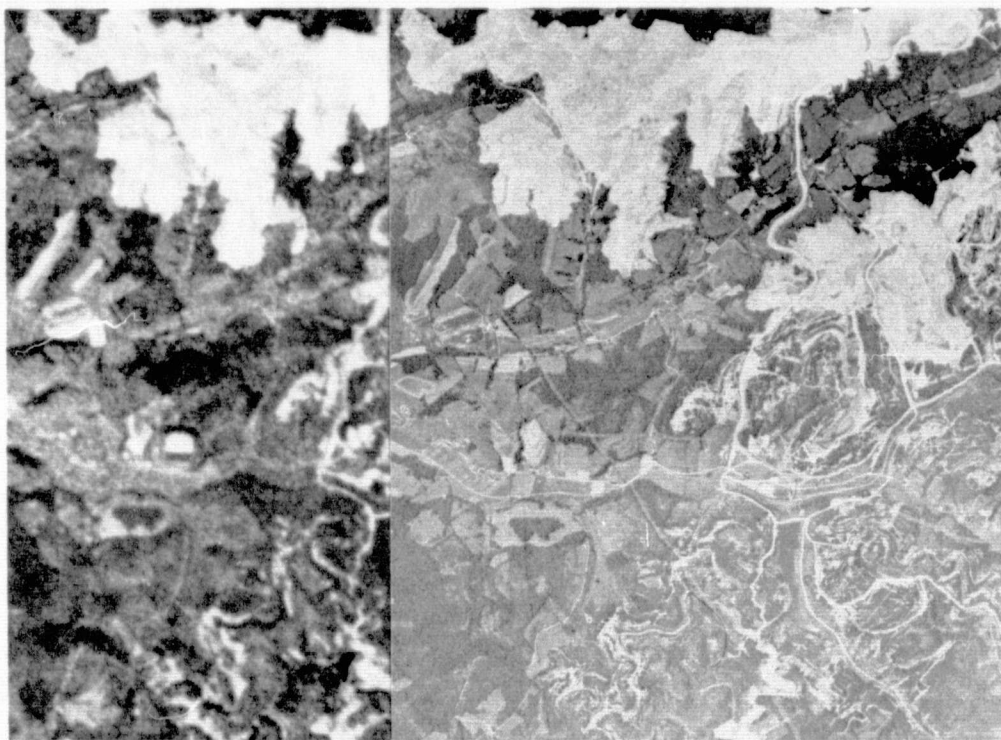
had been flown by DNR. By viewing the Skylab imagery and one frame of aircraft imagery through a wild mirror stereoscope at 1X and 3X magnification, a stereo effect similar to that achieved through aircraft imagery taken with a 60-75% overlap was observed. The stereo effect is quite vivid - as can be seen in Figure 14. This finding has cost savings implications in that requirements for conventional aircraft underflight data could be cut in half. Underflight data currently flown by NASA would require only sufficient overlap (usually 10%) to provide continuity in the photo strip, instead of the current 50-60%. The stereo effect can also be produced with virtually any aircraft data. By viewing aircraft data obtained as much as two years earlier, analysis would be able to detect changes in the terrain. Thus, by viewing the Skylab data with another conjugate image taken in a different time interval, both a height effect and a temporal effect could be observed. A detailed analysis of the resulting stereo model will be required however, to determine the quantitative aspects of the results. All analyses made so far, were made strictly on a qualitative basis.

Skylab Data Comparison to Ohio Land Reborn Study

In 1973, the Ohio Department of Natural Resources conducted a study, using high altitude aerial photographs and field surveys to identify and outline strip mine lands and to define existing physical conditions at each site.

Mined land definitions included determining:

- . Strip mine boundaries
- . Exposed highwalls
- . Exposed ponds



SKYLAB 190B

AIRCRAFT

FIGURE 14. STEREO EFFECT PRODUCED BY COMBINING S190B
COLOR IR AND PANCHROMATIC AERIAL PHOTOGRAPHY
(Scale 1:80,000)

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- . Degree of regrading
- . General slope of the adjacent land surfaces
- . Amount of vegetation cover present.

These parameters constituted a matrix from which a six category ranking system was established to distinguish the type of reclamation required, as follows:

Map Classification

1. Active land
2. Completely reclaimed land
3. Minimal reclamation effort required
4. Moderate reclamation effort required
5. Extensive reclamation effort required
6. Coal refuse piles.

Field Classification

- A. Ungraded
- B. Partially Regraded
- C. Completely Regraded
- D. Unvegetated (40% cover)
- E. Partially revegetated (40-80% cover)
- F. Completely Revegetated (80% cover)
- G. Level Slope (10°)
- H. Moderate Slope (10°-20°)
- I. Steep Slope (20°)

Thus, a given strip mined area designated as ADG4 meant that it was ungraded (A), less than 40% covered by vegetation (D), sloped less than 10° (G), and required moderate reclamation effort (4).

Skylab imagery was analyzed to determine which of the above elements of the field and map classifications could be derived. The results compiled in Table 5 show where Skylab photography could, with 95% accuracies, identify a certain strip mine feature or condition, and where aircraft photography is currently required for successful analysis.

The analysis showed that out of thirty feature combinations which were identified from aircraft imagery during the Land Reborn Study, fifteen could be identified from Skylab S190B IR Color photography. The remainder could have been identified from Skylab data if the Skylab imagery displayed a stereo effect, enough to detect 10° slopes on the ground.

As discussed previously, by combining conjugate Skylab and aircraft photography, equally scaled, stereo viewing can provide slope information. Thus, although still requiring photogrammetric calibration, grading and slope parameters may be determinable by combining orbital and aircraft photographs.




For actual data comparison, Skylab Color Infrared S190B photography taken September 15, 1973, was used. The photography was enlarged from an original scale of 1:950,000 to a scale of approximately 1:80,000 and was printed in black and white on drafting mylar. This scale was chosen to approximate the scale of the aircraft imagery used in the Land Reborn Study. An overlap of the watershed boundary was prepared by enlarging a 1:250,000 map showing watershed boundaries provided by ODNR. The Skylab imagery was interpreted for the Southeastern Coshocton County watershed using the following as interpretative criteria in delineating strip mine boundaries.

- (1) Areas of active strip mining (unvegetated)
- (2) Areas of present regrading efforts (unvegetated)
- (3) Areas which have been stripped in the past but show revegetation in varying degrees

TABLE 5. SKYLAB DATA INTERPRETATION CAPABILITY VS LAND REBORN STUDY
Field and Map Classification Matrix

Map Classification Field Classification	1* Active	2 Completely Reclaimed	3 Minimal Reclamation Required	4 Moderate Reclamation Required	5 Extensive Reclamation Required	6* Refuse Piles
A. Ungraded	S	S	S	S	S	
B. Partially Graded	S	A/C	A/C Stereo	A/C Stereo	A/C Stereo	
C. Completely Graded		S	S	S	S	
D. Unvegetated (0-40% cover)	S			S	S	
E. Partially Revegetated (40-80% cover)	S		S	S		
F. Completely Revegetated (>80% cover)		S	S			
G. Level Slope (> 10%)	A/C Stereo	A/C Stereo,W	A/C Stereo,W	A/C Stereo	A/C Stereo	
H. Moderate Slope (10-20%)	A/C Stereo	A/C Stereo,W	A/C Stereo,W	A/C Stereo	A/C Stereo	
I. Steep Slope (> 20%)	A/C Stereo	A/C Stereo,W	A/C Stereo,W	A/C Stereo	A/C Stereo	

TABLE 5. SKYLAB DATA INTERPRETATION CAPABILITY VS LAND REBORN STUDY
Field and Map Classification Matrix
(Continued)

S	=	Can be identified with S190B data.
A/C	=	Requires aircraft stereo photography - could be performed with S190B data if stereo coverage of 50-60% overlap or equivalent.
W	=	Requires winter photography to discover slope in densely wooded areas.
	=	Not applicable to <u>Land Reborn</u> Study.
	=	Not applicable to <u>Land Reborn</u> Study, but can be identified.
	=	Not applicable.
*	=	Not evaluated in <u>Land Reborn</u> Study.

- (4) Areas not stripped but which have been directly affected by strip mining activities, e.g., covered by overburden.



As these areas were identified, they were outlined on transparent film covering the mylar image providing the overlay to the photo, see Figure 15. A second overlay, Figure 16, was made using the strip mine classification from the Land Reborn Study for the same watershed. The extent of agreement is apparent by comparing Figures 15 and 16. Few features not discernible in Skylab S190B are also delineated on Figure 15.


For verification purposes, strip mined areas located in this watershed were analyzed on 1:80,000 scaled panchromatic photography provided by ODNR. The photography had been flown in August, 1973, for the Ohio Land Reborn Study. The aerial photos were interpreted using a Wild Mirror Stereoscope. The criteria used in the photo analysis were the same four used in the Skylab interpretation. The aircraft and Skylab interpretation comparisons produced the following findings.

Regrading and stripping operations were the most apparent features observed in the Skylab photography (S190B). Areas covered by varying degrees of vegetation were also identifiable. Highwalls and impoundments were identifiable and only limited by their size and shadow detail. Land which has been thickly revegetated had the appearance of being completely reclaimed and was difficult to identify as having been stripped. However, in most cases, highwalls and ponded water remain that indicate past stripping operations. Once these were identified, the area in doubt could be delineated. Areas with no highwalls or ponded water which have been completely revegetated could not, in the majority of cases, be identified. Refuse piles from underground mining activities could not be identified on either Skylab or aircraft photos.



FIGURE 15. WATERSHED IN SOUTHEASTERN COSHOCTON COUNTY, OHIO WITH STRIP MINED LAND AS DELINEATED FROM SKYLAB S190B COLOR IR. Scale 1:80,000

 Water Impoundments
 Highwalls
 ----- Strip Mine Boundaries

 Strip Mine Features Identified
 in Land Reborn Study not
 delineated on Skylab photography

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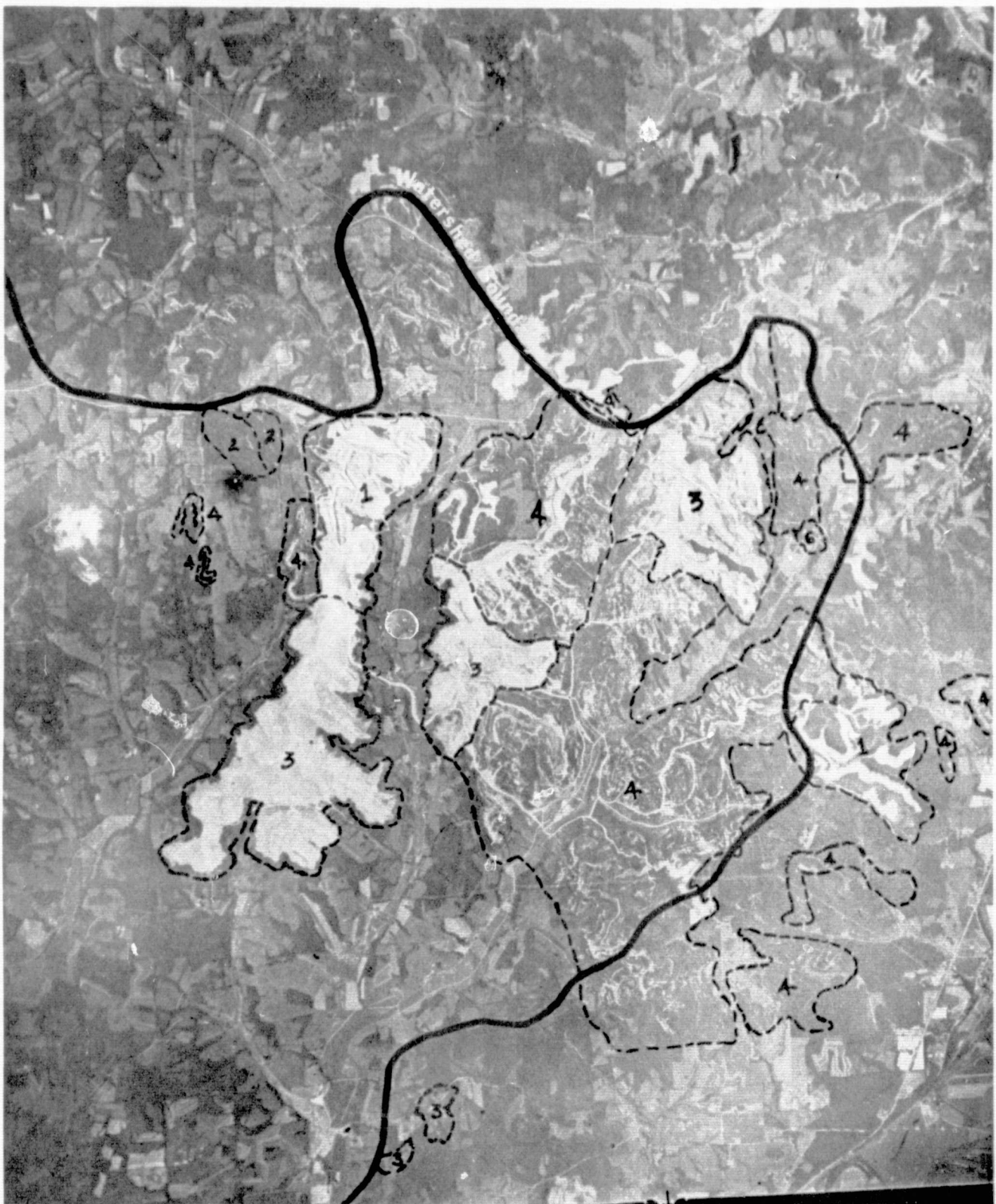


FIGURE 16. WATERSHED IN SOUTHEASTERN COSHOCTON COUNTY, OHIO WITH SURFACE MINE FEATURES AS INTERPRETED AND CLASSIFIED ON AIRCRAFT PHOTOGRAPHY (Scale 1:80,000) IN OHIO LAND REBORN STUDY

Map Classification of Strip Mined Land

- | | |
|--|--|
| 1. Active | 4. Moderate Reclamation Effort Required |
| 2. Completely Reclaimed | 5. Extensive Reclamation Effort Required |
| 3. Minimal Reclamation Effort Required | 6. Coal Refuse Piles |

~ Highwalls

-----Strip Mine Boundaries

Slope angles were not measurable on Skylab photography because of lack of adequate stereo parallax but could be approximated by viewing conjugate aircraft and Skylab data.

Thus, due to the ability of Skylab photography to resolve detail to the extent needed in analyzing stripping and reclamation operations, such photography could be used for most of the Land Reborn Study needs with the exception of slope-related information. Also, the aircraft imagery provided the capacity to identify slopes which in turn aided in identifying specialized features such as talus or out slopes. Such slopes in the Skylab photography blend with background stripping operations and although detectable are not identifiable.

Mined Land Restoration Program/Analysis

The previous analysis determined to what extent Skylab scale photography could provide information on coal surface mining features of the type required for current mining and reclamation monitoring. Of current Ohio user interest is the extent that such satellite data (if repetitively available) can be cost-effectively utilized in orphan mined land restoration projects and activities. This user interest can be further divided into what impact such data can have on: (1) planning in relation to mined land capability analysis efforts; and (2) monitoring in relation to site restoration progress once implemented.

Mined Land Capability Analysis. In pilot restoration projects, the ODNR is testing a methodology for translating their computerized OCAP (Ohio Capability Analysis Program)⁽¹⁾ techniques/capabilities to the data/information requirements associated with restoration of mined lands. In brief, this program allows for the storage and combined retrieval and mapping of data for a

wide variety of physical and cultural features for various land analysis applications. Specifically for application to mined land restoration, the following physical data groups are considered relevant:

Soils	Ground Water
Slope	Oil and Gas Well Locations
Recharge Areas*	Land Cover
Surface Water	Geologic Hazards (Including highwalls, water impoundments, etc.)
Mine Spoil (Stone Cover)	Mined Land Location
Mine Spoil (Acidity)	Mine Spoil (Slope)

Since one popular mapping scale used in the OCAP analysis is the conventional 1" = 2,000' (USGS 1:24,000 scale) and the minimum land unit of concern is approximately one acre, the responsiveness of Skylab type data was evaluated in relation to these routine user information criteria. Table 6 shows the qualitative results of analyzing S190B infrared color imagery at the 1:24,000 scale for the various physical data groups of current land capability analysis interest.

Restoration Activities. Because the reclamation/restoration process is a long-term effort which requires periodic monitoring and frequent program adjustment to be most successful, another logical user interest related to how effectively changes in critical physical parameters can be discerned and monitored in repetitive satellite photography. Examples of such parameters of current baseline concern to mined land development and utilization include:

- (1) Slope condition
- (2) Erosion

(1) For a report on this program and its applications see "Land Capability Analysis" ODNr, 1974.

* Layers of permeable material through which an appreciable amount of water may pass.

TABLE 6. QUALITATIVE ESTIMATE OF SKYLAB DATA USE
POTENTIAL FOR OHIO SURFACE MINED LAND
RESTORATION INTERESTS

Physical Data Group	Skylab 190B Use Potential	Identification Accuracy	Minimum Area Discernible (in hectares, ha)
1. Land Cover			
(a) Abandoned Fields	Moderate	50-90%	5 ha
(b) Bare Soil/Mined Lands	High	90-100%	1/2 ha
(c) Cover Crops/Grassland	Moderate	50-90%	5 ha
(d) Woodlots (deciduous)	High	90-100%	1 ha
(e) Woodlots (coniferous)	High	90-100%	1 ha
(f) Marshland/ Open Water	Moderate	50-90%	10 ha
(g) Orchards/Row Crops	Low	0-25%	5 ha
(h) Urban/Residential	High	90-100%	1 ha
(i) Mined Lands (with deciduous cover)	Moderate	50-90%	1-5 ha
2. Soil Condition	None	None	None
3. Hazards			
(a) Highwalls	High	50-90%	Not applicable
(b) Water Impoundments	High	90-100%	1/2 - 1 ha
4. Slope	Low (requires improved stereo parallax or use in combination with A/C)	--	--
5. Surface Water (Location only)	High	90-100%	1/2 - 1 ha
6. Recharge Areas	None	--	--
7. Mine Spoils			
(a) Stone Cover	Low	--	--
(b) Acidity	None	--	--
8. Ground Water	None	--	--
9. Oil and Gas Well Location	None	--	--
10. Mined Land Location	High	90-100%	1/2 ha

- (3) Acid drainage
- (4) Soil condition
- (5) Vegetation cover
- (6) Highwall and spoil pile locations.

Current Skylab type photography can only provide direct inputs to items (5) and (6). Other inputs would be indirect or would rely on correlations with aircraft or ground truth data. However, the specifics of these opportunities and limitations of using satellite data should be researched in more detail than was possible in this subtask.

Following determination of the baseline data, restoration recommendations as to necessary actions required are formulated. These recommendations include such actions as grading, soil neutralization and development, and seeding. Currently, Skylab type data can contribute directly to evaluating seeding/revegetation success but would have to be used in combination with aircraft or ground truth data to provide adequate input for most other parameter evaluation. However, by modifying future satellite coverage to improve stereo viewing would be extremely useful for the slope/grading monitoring function. Another possibility requiring evaluation is the potential of using Skylab type data in stereo combination with aircraft photography to provide topographic information.

User Assessment

The Ohio Department of Natural Resources

The Ohio Department of Natural Resources has two distinct responsibilities in the field of mining and reclamation:

- (1) Current mining and its reclamation
- (2) Reclamation of unreclaimed lands.

Remote sensing requirements for current mining and reclamation are basically in the area of monitoring. Departmental monitoring in the mining and reclamation field is concerned with the following:

- . Is mining maintained in the licensed area?
- . Is mining being accomplished without harm to adjacent areas?
- . Is reclamation being accomplished according to license requirements?
- . Has reclamation been successful?

This program has demonstrated that the spectral and spatial capabilities of the Skylab cameras are adequate to meet most of these monitoring requirements. Specifically, mining sites can be located and their operational area compared to license specifications. If significant harm is being done to adjacent areas, it can be detected and curtailed. The development of healthy vegetation can also be evaluated and the success of reclamation determined. Uncertainties still exist relative to the extent that grading and sloping can be determined to fulfill license requirements. And finally, Skylab sensors can also be utilized to locate mining operations that are not, but should be, licensed. This is a problem more so in the surface mining of minerals other than coal.

The development of an unreclaimed (orphan) lands program has the same requirements as the current mining program listed above or more. Such a program has two basic requirements:

- . Location of unreclaimed areas
- . Evaluation of the unreclaimed areas.

The location of unreclaimed areas can be accomplished now with the same demonstrated technology that can determine the extent of current mining operations. However, the evaluation of these unreclaimed lands is another

problem. There exists in Ohio about 346,000 acres of land requiring some sort of reclamation. All areas must be prioritized to insure those most in need of reclamation are reclaimed first. A remote sensing system that can accomplish this will save many man hours involving teams doing tedious ground evaluation, presently costing about \$35,000 a year. This figure includes personnel, subsistence and equipment. To prioritize future reclamation projects the remote sensing equipment must be able to not only locate unreclaimed areas, but indicate the extent to which problem has affected areas adjacent to those originally mined. From this data an evaluation can be made of probable socio-economic effects, on surrounding communities, that are caused by problems from the unreclaimed areas.

Once these priorities have been established, a second need arises to determine probable reclamation requirements and costs. To establish this, the following information is required.

- (1) Areas' physical condition, to determine Earth moving requirements.
- (2) Probable acid conditions.
- (3) Soil and spoil conditions relative to plant growth requirements.
- (4) Area conditions indicating probable future land use, to determine level of reclamation required.

The specific sensing parameters would probably only be indicators and their identification has yet to be accomplished.

Up to now the discussion has been on program needs relative to data requirements. Once the data has been recorded, the next need is its presentation and end use. There are probably several ways in which this can be done. One such system can be visualized as follows: The data is transmitted and recorded on tape. The tape data can be enhanced and rescaled if needed.

Next, the data would be run through a scanning device to accomplish a digitizing step based on density analysis. These data can also be compared with other OCAP data before a final evaluation is made.

For any major program this system would handle data quickly, accurately and require few people, thus reducing total costs and increasing efficiency. The currently available remote sensing information is relevant and useful in the reclamation program, but can and should be improved to be of even greater use especially in data handling.

Some satellite and aircraft data are being used in the State mining and reclamation program. As the program and the need for data becomes greater, so will the need for automatic remote sensing data processing. Increased data use will increase the need for automatic processing to eliminate tedious and expensive development of data. If the automatic system is not developed, the data will probably be little used.

Data requirements will vary with the program and time. Some programs may require data on a one time basis and other on a continuing basis, say once or twice a year. An evaluation of current Skylab type remote sensing equipment and results do show it to be a useful tool in large scale inventory projects. However, improvements are needed in types of sensors, size of area that can be evaluated, type of evaluation that can be made regardless of size, and perhaps most importantly, the automatic processing and presentation of data.

Therefore, a program to develop this total system should be initiated. Development of this program must be also accomplished by a user-developer team working together to obtain the most useful system.

TASK 3. CENTRAL OHIO AGRICULTURAL
LAND ENCROACHMENT ANALYSIS

TASK 3. CENTRAL OHIO AGRICULTURAL LAND ENCROACHMENT ANALYSISBackground

Land use problems related to urban growth are becoming increasingly important throughout the nation. Characteristic of these land use problems are the difficulty and expense of extending urban services to increasingly dispersed urban growth areas and the emergence of idle agricultural lands on urban peripheries because of high tax policies. Such problems are resulting in increased public control of land use in many areas through the United States. For example, increasing efforts to preserve agricultural land or to protect it from premature or haphazard conversion have occurred at the state and local level. Representative of these control measures are various innovative forms of preferential assessment of agricultural land values which have been adopted in more than thirty states including Ohio.

Over the last two decades, Ohio has experienced a decline in the total number of farms. The conversion of land from agricultural to urban-related land uses is an irreversible process. Thus, the trend is of potentially serious consequence to the supply of food and fiber products in Ohio and the nation as a whole if the "best" agricultural lands are among the lands being converted into urban developments.

Since most American cities are constantly in the process of growth, changing land use characteristics can best be identified from synoptic views provided from remote platforms, particularly the conversion of rural areas to developed areas on the peripheries of cities. The basic intent of this task was to establish the utility of Skylab data for identifying and assessing the impact of urban growth on agricultural activities. The results could be of value to state, regional, and local government.

Objectives and Scope

The general purpose of this task was to assess the potential of using orbital data (specifically Skylab EREP photography) for assisting state, regional, and urban planners in analyzing the urban growth-agricultural encroachment problem.

The specific objective was to develop a methodology for using Skylab imagery for analyzing urban growth and its impact on prime agricultural land.

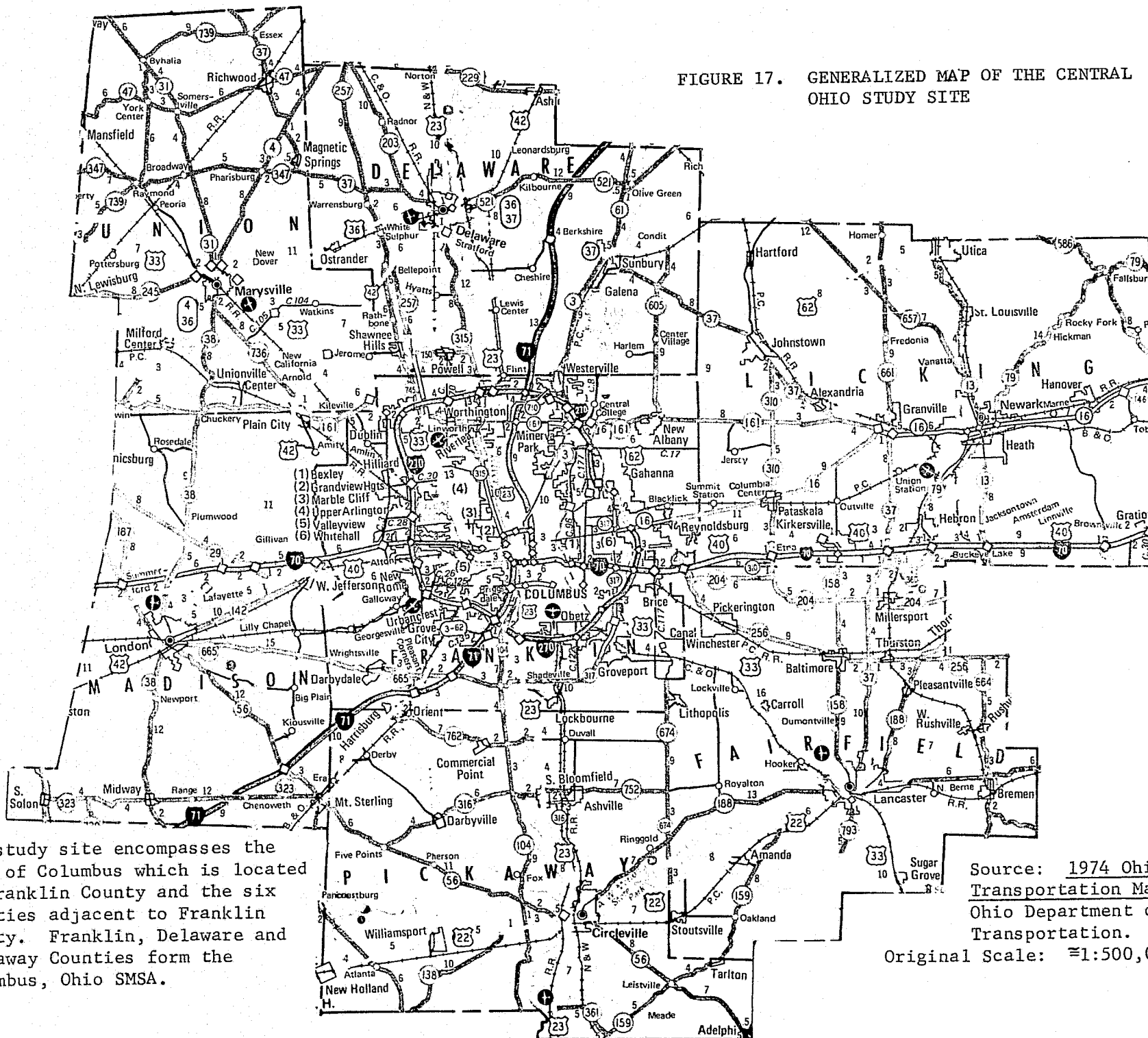
The Central Ohio area (including the City of Columbus, Franklin County and the 6 adjacent counties) was selected as a representative study site area. Manual analysis was made of the ability to delineate and map urban growth in relation to agricultural activities. User groups representing state, regional, and urban planning levels were involved in the end-user assessment of the practical significance of the results.

Research Analysis and Results

Figure 17 shows the seven county, central Ohio area selected as the study site. The area covers 10,231 km². Franklin County, which contains the city of Columbus, was chosen as the main study area. Surrounding townships and counties received only secondary analysis effort. To determine the extent and form of urbanization in the Columbus/Franklin County area, an eleven-year period between 1962 and 1973 was selected for analysis. The selection of this time interval was based primarily on the relatively rapid growth rate which Columbus experienced during the 1960's and because of the availability of pertinent reference and photographic data.

The generalized research procedure involved five closely related activities. These included:

FIGURE 17. GENERALIZED MAP OF THE CENTRAL
OHIO STUDY SITE



The study site encompasses the City of Columbus which is located in Franklin County and the six Counties adjacent to Franklin County. Franklin, Delaware and Pickaway Counties form the Columbus, Ohio SMSA.

Source: 1974 Ohio
Transportation Map,
Ohio Department of
Transportation.
Original Scale: $\approx 1:500,000$

- . Interaction/coordination with user groups
- . Analysis of urban growth
- . Analysis of urban growth relative to agricultural lands
- . Analysis of specific urban and agricultural features discernible on Skylab imagery
- . Analysis of user significance.

The analyses were directed toward two application scenarios: (1) planning in relation to urban growth - agricultural encroachment trends; and (2) regulatory functions in relation to implementing agricultural land tax legislation.

User Agency Interactions

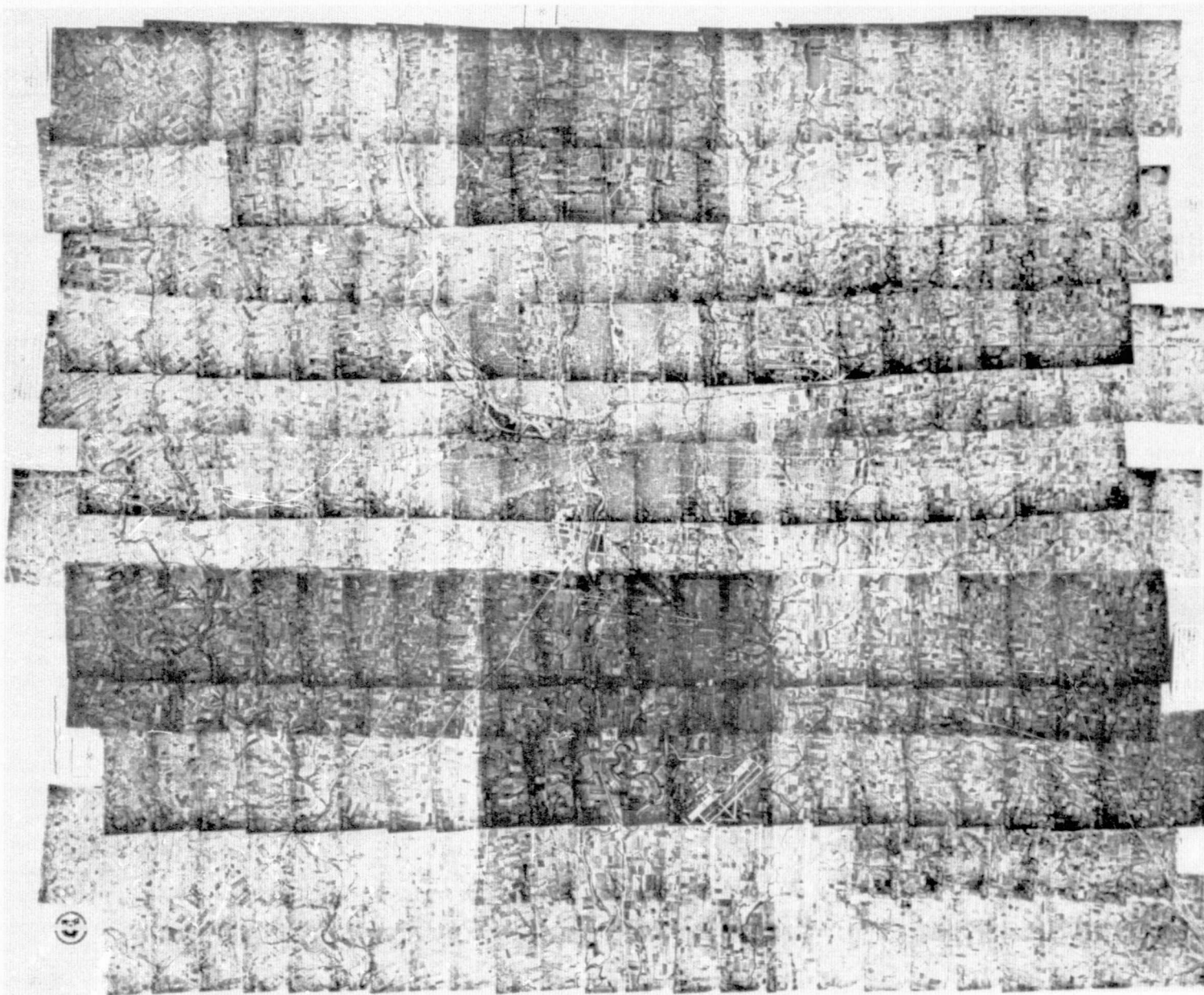
Representatives of governmental agencies involved in land use and developmental decision making in the Central Ohio area were invited to participate in a series of initial task meetings. These included representatives of the State of Ohio, the City of Columbus, the Mid-Ohio Regional Planning Commission and Battelle. Further discussions were held with personnel from the Franklin County Auditor's Office, Department of Real Estate Appraisal; the U. S. Department of Agriculture, Soil Conservation Service; the Franklin County Soil and Water Conservation District; the Franklin County Agricultural Stabilization and Conservation Service; the Ohio Cooperative Extension Service; and, the Ohio Board of Tax Appeals. The purpose of these interactions was to establish user interests and data requirements relating to urban growth and agricultural land encroachment. Unfortunately, except for strip development along major roadways linking urban and suburban areas and detailed land use interests, users were only moderately interested in the task itself.

Urban Growth

Reference maps, background data and aerial photography flown in 1962 for the study area were acquired and evaluated. Existing land use maps of the study area were too general and typically of scales too small to be used in the analysis. Accordingly, determination of the urban boundary in 1962 was done from aerial photography. Specifically, March, 1962, aerial index photography from the Ohio Department of Transportation (ODOT) was used. Twelve strip mosaics, each representing 25-30 aerial photographs, were laid into one semi-controlled mosaic, covering the total Columbus/Franklin County area at a scale of 1:120,000, see Figure 18.

Delineation, Mapping and Inventorying Urbanized Areas (1962). The boundaries of urban areas, which usually represent build-up areas along the urban-rural interface, were transferred to a transparent overlay. The overlay was then placed into a rear projector for manual transfer to a mylar base map. The base map was prepared from a July, 1975, Franklin County Highway map, which was photographically enlarged to a scale of 1:63,360. The base map contained primarily political boundaries and street detail within the county. The scale was chosen to provide sufficient detail for recognizing the extent of urban growth in any portion of the city. The total urban area was planimetered three times with a K&E Compensating Polar Planimeter Model 62 0000 and an average value of 24.2% urbanization determined.

Delineation, Mapping and Inventorying of Urban Growth. Photography taken by the SI90A multispectral camera over the Central Ohio area on September 15, 1973, was examined to determine which spectral bands reveal the most useful urban and agricultural information. The most useful imagery was



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FIGURE 18. MOSAIC OF COLUMBUS/FRANKLIN COUNTY, OHIO FROM 1:24,000 INDEX AERIAL PHOTOGRAPHY OF MARCH 21, 1962. The preponderance of plowed fields in this spring photography is an indicator of agricultural activities in the Columbus metropolitan area.

the 190A color and color IR. An enlarged black and white (S190A) photograph of the study site is shown in Figure 19. S190B coverage which provided the better resolution was unfortunately only available for the southeastern portion of the study site, and was therefore used mostly for a second-level analysis of urban features discernible. The color and infrared color S190A imagery provided by NASA in the 240 mm format was then alternately rear projected on the 1:63,360 scale basemap already containing the 1962 urban-rural demarcation lines. The imagery was registered until six major intersections scattered across the imagery coincided with the corresponding intersections appearing on the basemap. During this process linear errors of 2 mm were noted. Comparison with linear dimensions on a 1:24,000 map of selected areas, showed that the 2 mm error was in the original highway map and not the Skylab imagery. The total 1973 urban area was planimeted three times with the K&E Compensating Polar Planimeter, and the average value of 37.8% urbanization calculated.

Urban Growth Analysis (1962-1973). This phase of the analysis determined the extent and form of growth occurring in the City of Columbus/Franklin County area. Total growth and directional trends were used in a subsequent assessment of the seriousness of the current agricultural land encroachment trend in the study site area. The overall urban growth statistics are shown in Table 7. In the slightly over 10 year period Columbus/Franklin County experienced a 13.6% urbanization increase having a total of 37.8% of the county in urban areas in 1973. This represented an actual increase in the original urban area of 56% which occurred during the 1962-1973 period.

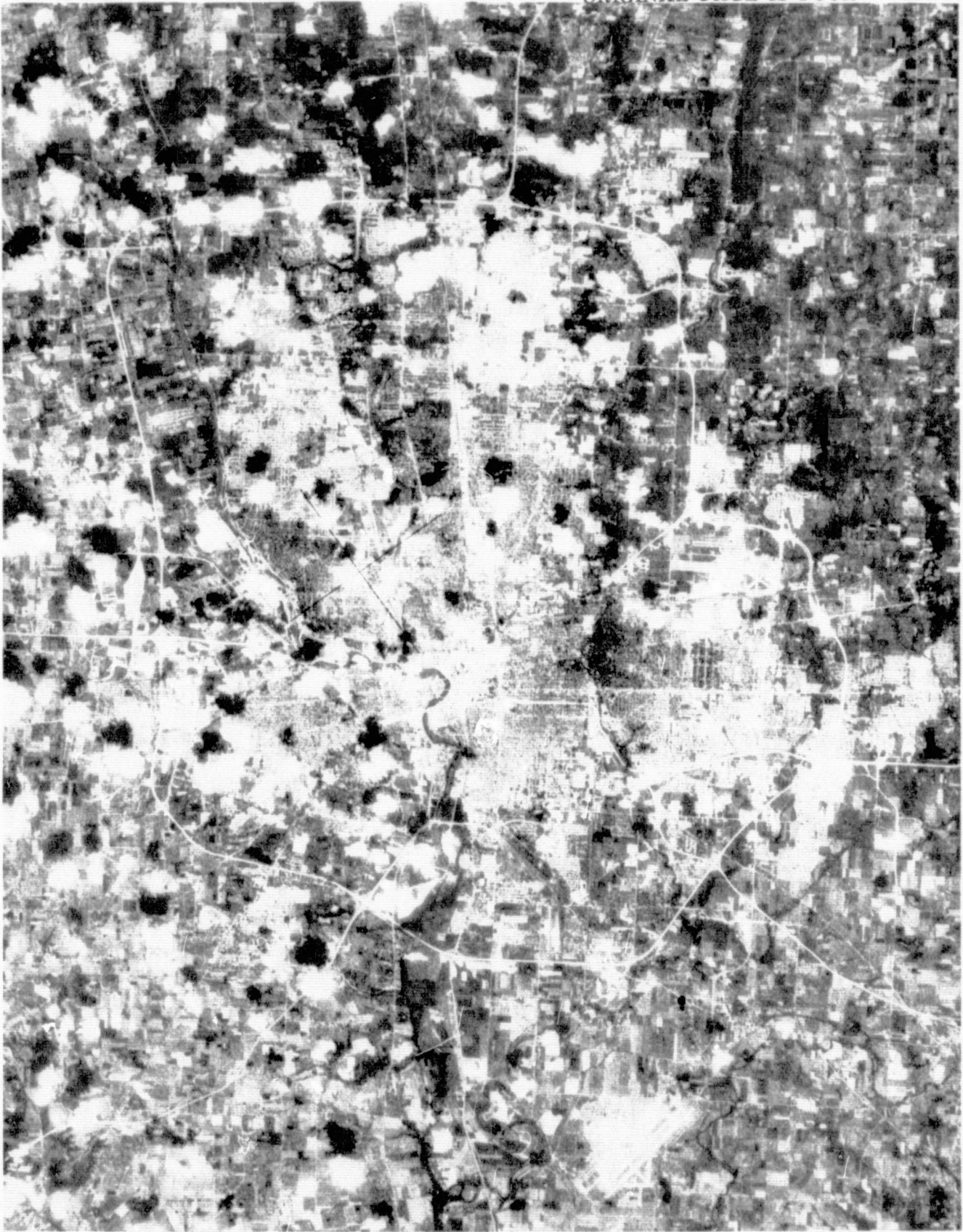


FIGURE 19. SKYLAB 190A PHOTOGRAPH OF AUGUST 15, 1973 SHOWING FRANKLIN COUNTY AND PORTIONS OF THE CENTRAL OHIO STUDY SITE AREA.

Scale \approx 1:200,000

TABLE 7. 1962-1973 COLUMBUS/FRANKLIN COUNTY,
OHIO URBAN GROWTH STATISTICS

	Square Miles	Acres	Hectares	% of County
1962 Urbanized Areas	130	83,200	33,700	24.2
1962-1973 Urban Growth Areas	73	46,720	18,900	13.6
Total Urbanized Area 1973	203	129,920	52,600	37.8
Franklin County Area	538	344,320	139,400	

In general, much of the development on the urban fringe resulted from natural population growth, rural to urban migration, and movement from the higher residential densities of the central city to the lower residential densities in the suburbs. Other factors relating to the general urban growth that occurred in the Columbus urban-rural fringe include dispersion of business activities from the central business district, land speculation, highway developments, and recreational facilities. However, the I-270, interstate outerbelt highway which surrounds Columbus (construction begun in 1962 and was nearly completed in the fall of 1973 when the Skylab photography was acquired) was the major "attractor" of new growth since significant amount of growth tended to be directed from the central city towards the outerbelt or along the outerbelt at major highway intersections. Urban growth will most likely continue outward from the central city to the outerbelt and beyond in a total circular pattern. Urban growth in this region can still be influenced, however, by local governmental actions (such as zoning, public utilities, and transportation) which could minimize prime agricultural land encroachment.

Strip development, occurring along major highways from Columbus to the adjacent cities of Delaware, Newark, Lancaster, Circleville or London, was not significant. These cities are all about 40 km from the center of Columbus. As shown in Figure 20, Skylab photography shows some isolated developments along the highways. Analysis of aircraft photography and ground truth surveys conducted by driving along the major highways from Columbus to these outlying cities confirmed some development, adjacent to the highways but no extensive areas that could be classified as strip development could be found at this time.

Urban Growth Encroachment on Agricultural Land. To acquire the proper perspective as to the overall relationship of urban growth to agricultural land encroachment required the preparation of the map shown in Figure 21. (Once again, the original map scale is the conventional 1 inch to a mile). This map combines the results of the urban boundaries delineated in the 1962 aerial photography and the Skylab 1973 photography with the better agricultural lands (by Township) in Franklin County as established by a survey of local representatives of the Agricultural Stabilization and Conservation Service, Ohio Cooperative Extension Service, and the Soil Conservation Service. Those lands, yielding higher average productivity yields per acre, are located around Hillard in Norwich and Brown Townships (Western Franklin County); around Grove City in Pleasant and Jackson Townships (Southwestern Franklin County); and Groveport and Canal Winchester in Madison Township (Southeastern Franklin County). An analysis of the growth pattern of the Columbus urban area showed that urbanization is beginning to expand into three of the four townships. Using 1975 township boundaries, the percentages of urban growth in these townships during the period under analysis are shown in Table 8.

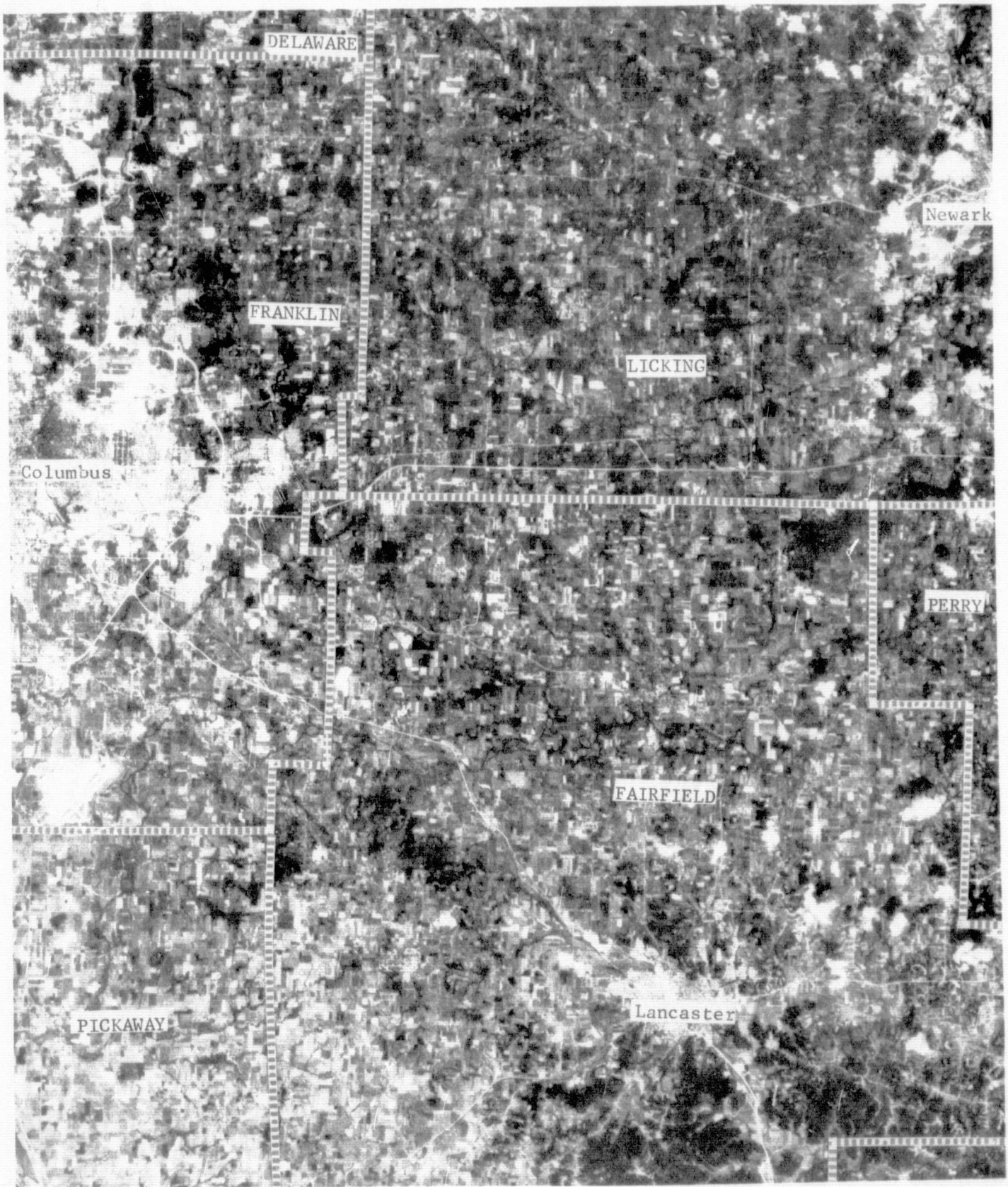


FIGURE 20. ENLARGEMENT OF A SKYLAB EREP S190A PHOTOGRAPH SHOWING PORTIONS OF FRANKLIN, LICKING, FAIRFIELD, PICKAWAY, AND PERRY COUNTIES, OHIO.

The preponderance of agricultural activities are readily noticeable as is the lack of definable urban strip development between Columbus and Newark or Lancaster.

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**URBAN GROWTH-AGRICULTURAL LAND ENCROACHMENT PATTERN
COLUMBUS/FRANKLIN CO., OHIO (1962-1973)**

- URBANIZED AREAS 1962
- URBAN GROWTH 1962-1973
- TOWNSHIPS CONTAINING MOST PRODUCTIVE AGRICULTURAL LAND



FIGURE 21. URBAN ENCROACHMENT ON AGRICULTURAL LAND IN CENTRAL OHIO
(From Skylab 190A Data) ORIGINAL PHOTOGRAPH IN COLOR

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TABLE 8. URBAN GROWTH ENCROACHMENT TREND ON MOST PRODUCTIVE
CENTRAL OHIO AGRICULTURAL TOWNSHIPS (From Skylab 190A data)

Township	Prior To 1962	1962-1973 Change	1973 Total Urban
Madison	6%	+9%	15%
Jackson	6%	+7%	13%
Norwich	14%	+5%	19%
Brown	0%	0%	0%

Detailed Analyses of Urban and Agricultural Features. A detailed manual photointerpretative analysis of S190A and S190B imagery obtained in August and September, 1973, showed that Level I, II, and III* *urban* land use information can be extracted from such orbital data. Pertinent data regarding urban growth or growth patterns were identifiable from both S190A and S190B data. The capacity for determining type of growth, i.e., the kind of urban structures, required a certain minimum size and/or verification from aircraft underflight or ground truth data. For example, three single urban dwellings clustered together in a 1/2 to 1 hectare area could be readily identified. A warehouse, by contrast, covering 3-5 hectares in order to be identified as a type of commercial structure, would require aircraft data for positive identification. Table 9 is a summary of the urban feature detail discernible in Skylab imagery using all available film types.

A detailed analysis of *agricultural* features in S190A and S190B data obtained in August and September, 1973, showed that Level I and II detail is

* USGS Land Use Categories

TABLE 9. CENTRAL OHIO URBAN FEATURES DISCERNIBLE ON SKYLAB EREP PHOTOGRAPHY

LEVEL I		LEVEL II		LEVEL III		Distinguishing Characteristics
Feature	Status	Feature	Status	Feature	Status	
1.0 Urban and Build up	(1)	01. Residential	(1)	001. New Residential (0-15 years)	(1)	Clustered pattern of houses, driveways, roads, new lawns, sparse tree cover.
				002. Intermediate Resid.(15-25 yrs)	(1)	Clustered pattern of houses, driveways, roads, established lawns and intermediate tree cover.
				003. Old Residential(25 and older)	(1)	Patterns of houses, driveways, etc., obscured by tree cover.
		0.2 Commercial and services	(2)	001. Major Shopping Centers	(2)	Large asphalted parking areas and structures located near primary roads usually surrounded by heavily urbanized areas.
				001. Major manufacturing Plants, Distribution Centers	(2)	Large regular shaped structures and parking surfaces.
		0.3 Industrial	(2)			
		0.4 Extractive	(1)	001. Stone, Gravel, Sand	(1)	Large irregular shaped areas devoid of vegetation, with gravel or secondary access roads.
				001. Interstate Highways	(1)	Wide, linear and curved concrete or asphalt surfaces, with median strip.
				002. Primary and Secondary Roads	(1)	Usually newer than interstates sometimes obscured by vegetation, primary asphalted.
		0.5 Transportation, Communication, and Utilities	(1)	003. Railroads and Railroad Yards	(1)	Thin linear features, with expanded pattern in R.R. yards.
				004. Power Corridors	(1,2)	Usually discernible where natural vegetation cover has been cut, large towers carrying electric lines visible.
				005. Airports	(1)	
		0.6 Institutional	(3)	001. Hospital, Universities, Schools	(3)	
		0.7 Strip and Clustered Settlement	(1)	001. Residential, Industrial, Commercial	(1)	Observed along major highway arteries, usually characteristics of built up areas.
		0.8 Mixed	(1)	001. Urban Core Areas	(1)	Very dense structures located in center of urban areas with little, if any, tree cover.
		0.9 Open and Other (including recreational)	(1)	001. Woodlands	(1)	Moderate to dense tree crown closure.
				002. Parks	(2)	Moderate to dense tree crown closure with access roads and open field.
				003. Cemeteries	(2)	Appearance of open field, sometimes with moderate tree cover.
				004. Golf Courses	(1)	Apparent plant vigor.
2.0 Water		0.1 Streams and Waterways	(1)			Sharply delineated features. Detectability of streams affected by sedimentation and trees lining the waterway.
		0.2 Lakes	(1)			
		0.3 Reservoirs	(1)			

Legend: Status (1) Identifiable from Skylab data 90% of the time.
 Status (2) Recognizable from Skylab data by geometry, texture, color and/or alignment but not positively identifiable unless correlated with aircraft underflight or ground truth data.
 Status (3) Cannot be recognized.

extractable from orbital data, but that most Level III data require either verification from underflight photography or periodic or temporal coverage from orbital altitude. The minimum field size which may be delineated is 5 ha. In general, crop and forest land activities are clearly discernible; however, detection of feedlot and orchard operations will require much higher spatial resolution such as from high altitude aircraft photography. Table 10 shows extent of agricultural Level I, II, and III features that can be discerned on Skylab photography.

Agricultural Land Utilization and Taxation. In the General Election of November 6, 1973, Ohio voters overwhelmingly approved a State Issue on the ballot which gave the Ohio General Assembly the right to enact laws for assessing agricultural land for taxation in accordance with the agricultural use of the land. On July 26, 1974, the Ohio General Assembly amended the Ohio Revised Code "to provide for the evaluation of farmland in accordance with its current agricultural use value and a recoupment of tax savings upon the failure of the land to be so valued." Late in 1974, the Ohio Board of Tax Appeals adopted specific rules for determining the valuation of land qualified to be valued at its current agricultural use value for tax purposes effective with the 1974 tax year.

The provisions of Ohio's new agricultural land use assessment legislation are currently being carried out for the first time by each of Ohio's eighty-eight County Auditor Departments which disseminate and evaluate applications for the designation of agricultural lands for taxing purposes. A detailed soil map and an aerial map of each farm are required with the initial application form. When the applications are completed, the county auditor's department must view or cause to be viewed the land described in the application

TABLE 10. CENTRAL OHIO AGRICULTURAL LAND USE FEATURES DISCERNIBLE ON SKYLAB EREP PHOTOGRAPHY

LEVEL I		LEVEL II		LEVEL III		Distinguishing Characteristics
Feature	Status	Feature	Status	Feature	Status	
3.0 Agricultural Land	(1)	01. Cropland and Pasture	(1)	001. Corn	(2) or (T)	Field pattern and alignment, with constantly changing spectral image content. Texture and color differences as seen in Skylab imagery are too subtle to provide positive identification of crop types or pasture. However, temporal coverage or spot underflight photography would permit identification of crop patterns.
				002. Soybeans	(2) or (T)	
				003. Wheat	(2) or (T)	
				004. Grass and Pasture	(2) or (T)	
				005. Bare Ground	(1)	
				006. Other	(2) (T)	
		02. Orchards, Groves Bush, Fruits, Vineyards, and Horticultural Areas	(3)			
		03. Feeding Operations	(3)			
		04. Other		Forested Land	(1)	Dense to moderate tree cover.

Legend: Status (1) Identifiable from Skylab data 90% of the time.
 Status (2) Recognizable from Skylab data by geometry, texture, color and/or alignment but not positively identifiable unless correlated with aircraft underflight or ground truth data.
 Status (3) Cannot be recognized.
 (T) Temporal coverage required in Fall-Spring-Summer-Fall
 Smallest parcel of land identifiable as cropland = 5 ha

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and determine whether the land is land devoted exclusively to agricultural use. In addition, the county auditors are required to make and maintain an "agricultural land tax list" for each tract, lot, or parcel of land which has been valued for tax purposes as land devoted exclusively to agricultural use.

Each year the county auditor is required to reexamine the agricultural land tax list and determine if there has been a conversion of land devoted exclusively to agricultural use of any tract, lot, or parcel of land on the list. Upon the conversion of all or any portion of land devoted exclusively to agricultural use a portion of the tax savings upon such converted land are to be recouped by a charge levied on such land in an amount equal to the amount of the tax savings on the converted land during the four tax years immediately preceeding the year in which the conversion occurs. *The interest here was to determine if and to what extent Skylab type data could be used for this cost-consuming monitoring function.*

Table 10 summarizes the results of analyzing Skylab photography for agricultural features. The boxed areas of Figures 22 and 23 illustrate 30 acre plots as discerned from the aerial and Skylab photography. Thirty acre farms are generally the minimum sized areas required to be eligible for tax valuation as agricultural land. As shown, individual 30 acre tracts can be located without much difficulty on the photography, however, specific uses of the agricultural lands (feed lots, pastureland, cropland) are not determinable from single scene Skylab EREP photography. A comparison of SL-2 and SL-3 S190A photography illustrated that the potential of using repetitive, temporal Skylab type data for distinguishing crop types exists. Thus, future satellites with improved resolution could be very helpful to tax administrators in monitoring and verifying types of agricultural activities. Appropriate temporal coverage using *existing* Skylab photographic capabilities could be cost-effec-



FIGURE 22. AUGUST 28, 1973, NASA RB57 COLOR PHOTOGRAPHY OF THE COLUMBUS URBAN PERIPHERY IN EASTERN FRANKLIN COUNTY

The designated area is representative of a twelve hectare (thirty acre) farm. See Figure below for comparison.

Scale = 1:75,000 ORIGINAL PHOTOGRAPH IN COLOR

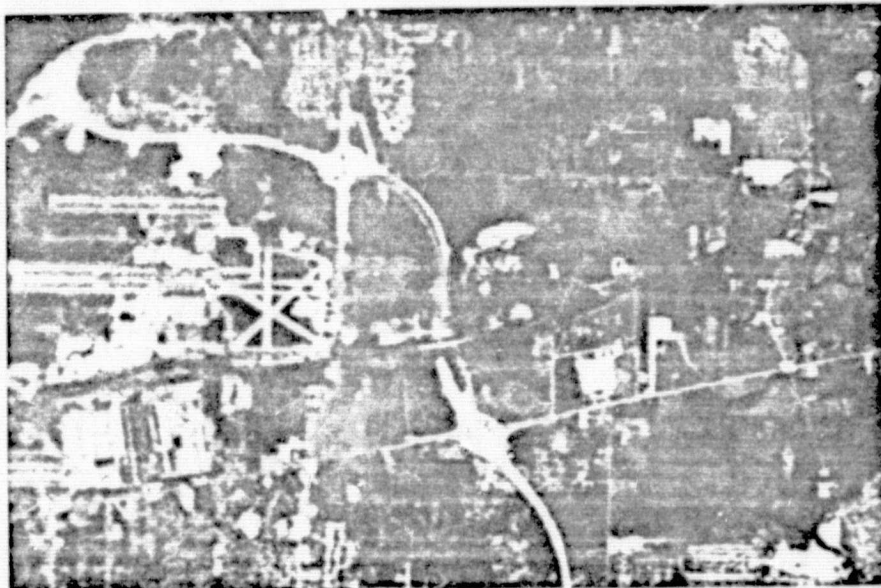


FIGURE 23. AUGUST 15, 1973, S190B PHOTOGRAPHY OF THE SAME FRANKLIN COUNTY AREA SHOWN ABOVE

The designated area is representative of a twelve hectare (thirty acre) farm. ORIGINAL PHOTOGRAPH IN COLOR

Scale = 1:75,000

tively used by county auditors enforcing tax laws to at least annually monitor and identify land use changes requiring more detailed and costly personnel inspection.

User Assessment

The Ohio Department of Economic and Community Development

Looking from the state perspective, the Ohio Department of Economic and Community Development has taken the change in Franklin County land use 1962-1973, as interpreted from Skylab EREP data, and assessed it's operational utility within the context of a State Development Planning Process. There are at least five major application areas in which the temporal change in land use, portrayed for an urban county at a general level of detail, can be operationally useful while making a significant contribution to the completion of on-going State planning programs. These five areas are outlined below.

- . The distribution of planning funds to local planning agencies is a major component of the State's Development Planning Process. The change in land use or growth distribution is a major criteria for allocating these funds among competing applications.
- . The federal Coastal Zone Management Act (CZM) requires the examination and consideration of economic and community development implications of land use changes in the shore zone.
- . The State is required, under new HUD planning regulations, to prepare, by 1977, a statewide land use and growth policy. The change in land use must be addressed in the forthcoming State policy.
- . The Development Planning Process has undertaken a major effort to develop a statewide economic development strategy as called for under Section 302 of the 1974 Economic Development Act. A key evaluation criteria to be used when operationalizing the strategy is the potential impact it will have on the change in land use.

- . Finally, it is generally true that State and local planners do not have an effective tool for evaluating the community development implications of various public and private policy decisions. These decisions, such as utility extensions, zoning amendments, density restrictions, and taxation, are generally made without consideration for their impacts on land patterns. The Development Planning Program has established a major State objective which calls for the development of a Growth Allocation Model which simulates the changes in community pattern resulting from alternative policy decisions. The expected change in land use becomes a key input to such a policy analysis model.

These five application areas represent a significant portion of State planning in Ohio. Total expenditures supporting the five areas are close to 1/2 million dollars annually. While this is certainly a significant sum of money, the size of the job represented by these five areas is enormous. Hence, there is constant pressure to maximize the productivity of the available resources. Maximizing the output with minimal consumption requires the use of all available information generated independently of the specific needs of each of the application areas. To date, the change in land use in urban counties has been borrowed from three sources.

- . Land use inventories, by traffic zones, which have been done as the result of highway projects. These are very detailed and limited to areas directly affected by the new highway. They are generally done on a one-time basis.
- . Land use base maps developed from aerial photographs. These are infrequently done (every 8-10 years) randomly updated and are generally not consistent over time or between different geographic areas.
- . Windshield surveys done by local planning agencies. These very detailed maps are done at great cost, infrequently updated and inconsistent in accuracy, format, etc.

Even using a combination of these three sources, it is impossible to compile a uniform set of land use maps or more importantly, to understand the change in land use patterns overtime for various geographic areas of the State. In short, we are presently forced to use patch work land use change

data which has many gaps and provides imprecise temporal comparisons. There are simply not enough State resources to generate a uniform systematic evaluation of land use change.

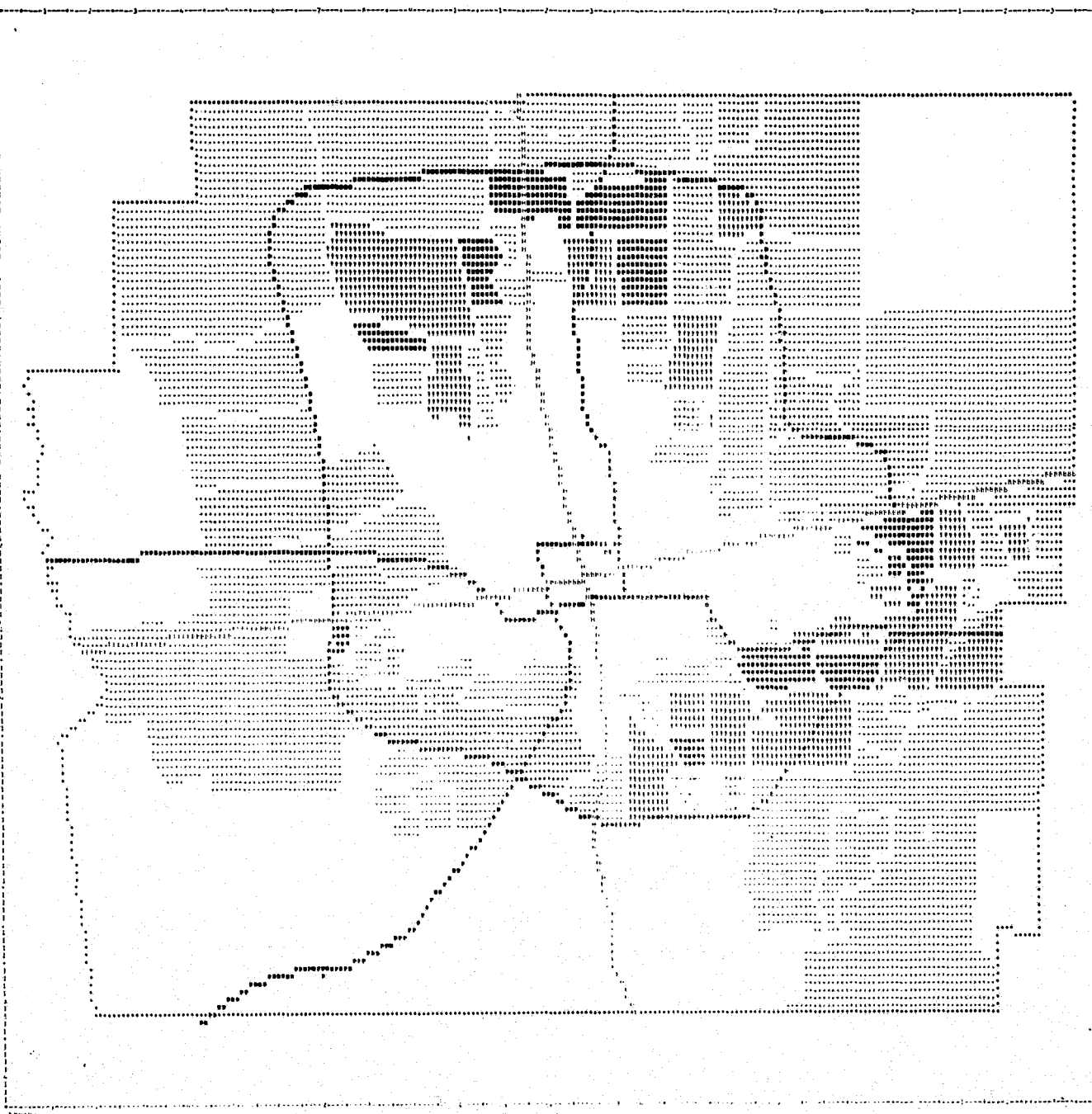
It is within this context of immediate and extensive needs, short resources and inadequate data substitutes that the change in land use developed from Skylab EREP data is received. The assessment approach utilized was as follows:

- . Skylab results were reformatted to fit our socio-economic data handling system.
- . The reformatted data was merged with related information already collected for the test site.
- . The Skylab results were then manipulated into the normal output used in daily operations.
- . The cost and applicability of this output were then compared with the data presently available from other sources.

The actual functional steps were as follows:

- (1) Since Franklin County is urbanized, the change as determined from Skylab was recorded for each census tract. There are 211 tracts in Franklin County. The tracts were ranked into five intervals: 0-25, 25-50, 50-70, 70-90, 90-100 percent change from non urban into urban use.
- (2) The change in land use by tract was placed into a previously developed geographic base file (county and tract outlines) for the county.
- (3) In this format the change in land use information was linked to the data handling system containing socio-economic data, a statistical analysis routine and a computer graphics routine.

The result of these three steps was the production of three computer maps showing the change in land use by tract (Figure 24), the change in population density 1960-1970 by tract (Figure 25) and the change in housing units by tract 1960-1970 (Figure 26). The latter two maps only show those tracts which had no change in boundaries during the period. Often, census tracts



FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

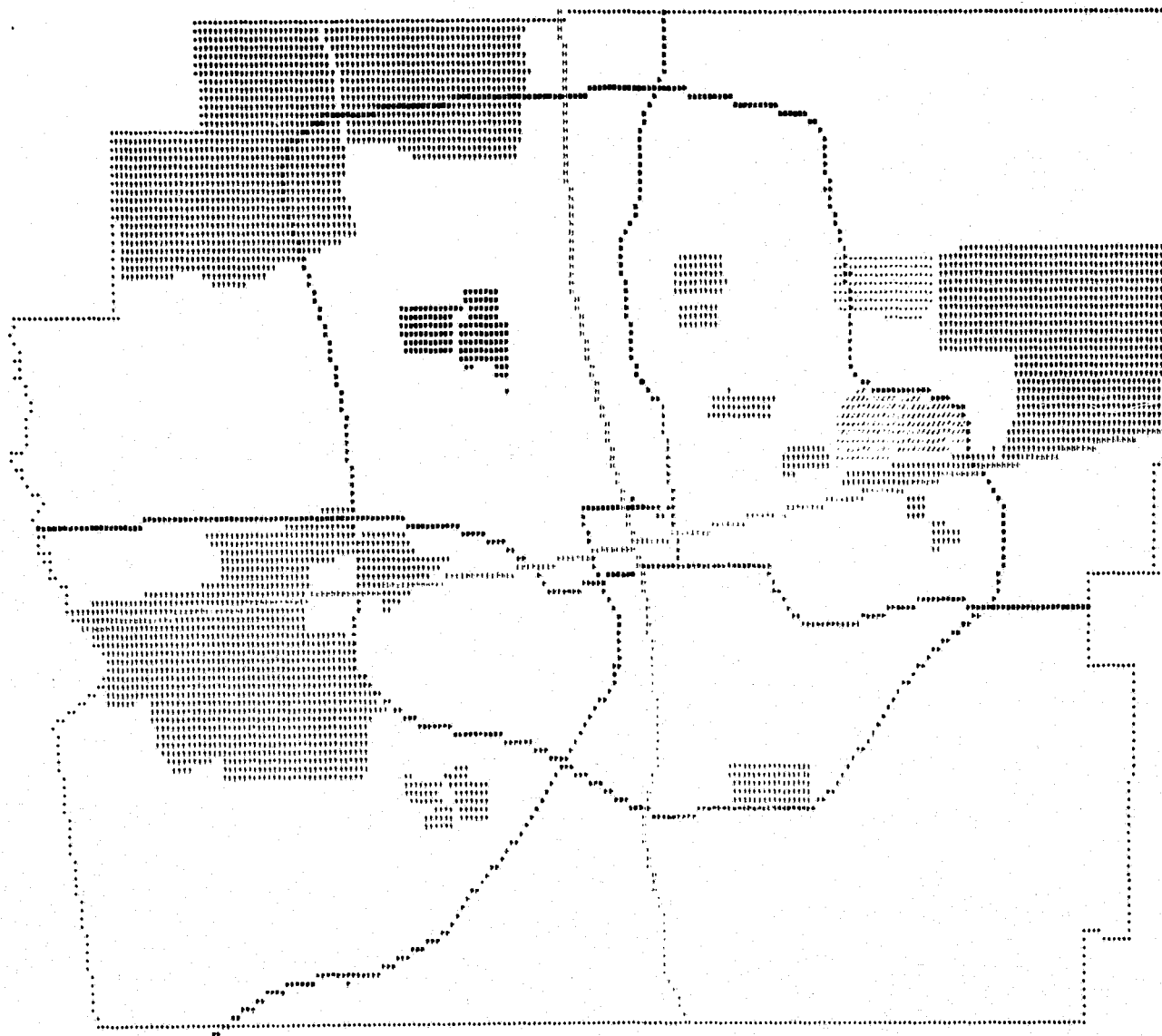
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SYMBOLS	*****	*****	*****	*****	*****
FREQ.	38	21	17	11	122
MINIMUM	25.00	47.52	70.05	91.71	113.37
MAXIMUM	47.52	70.05	91.71	113.37	200.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

12.67 12.87 12.36 12.38 49.50

FIGURE 24. COMPUTER MAP SHOWING CHANGE IN LAND USE, FRANKLIN COUNTY, 1960-1970

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FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

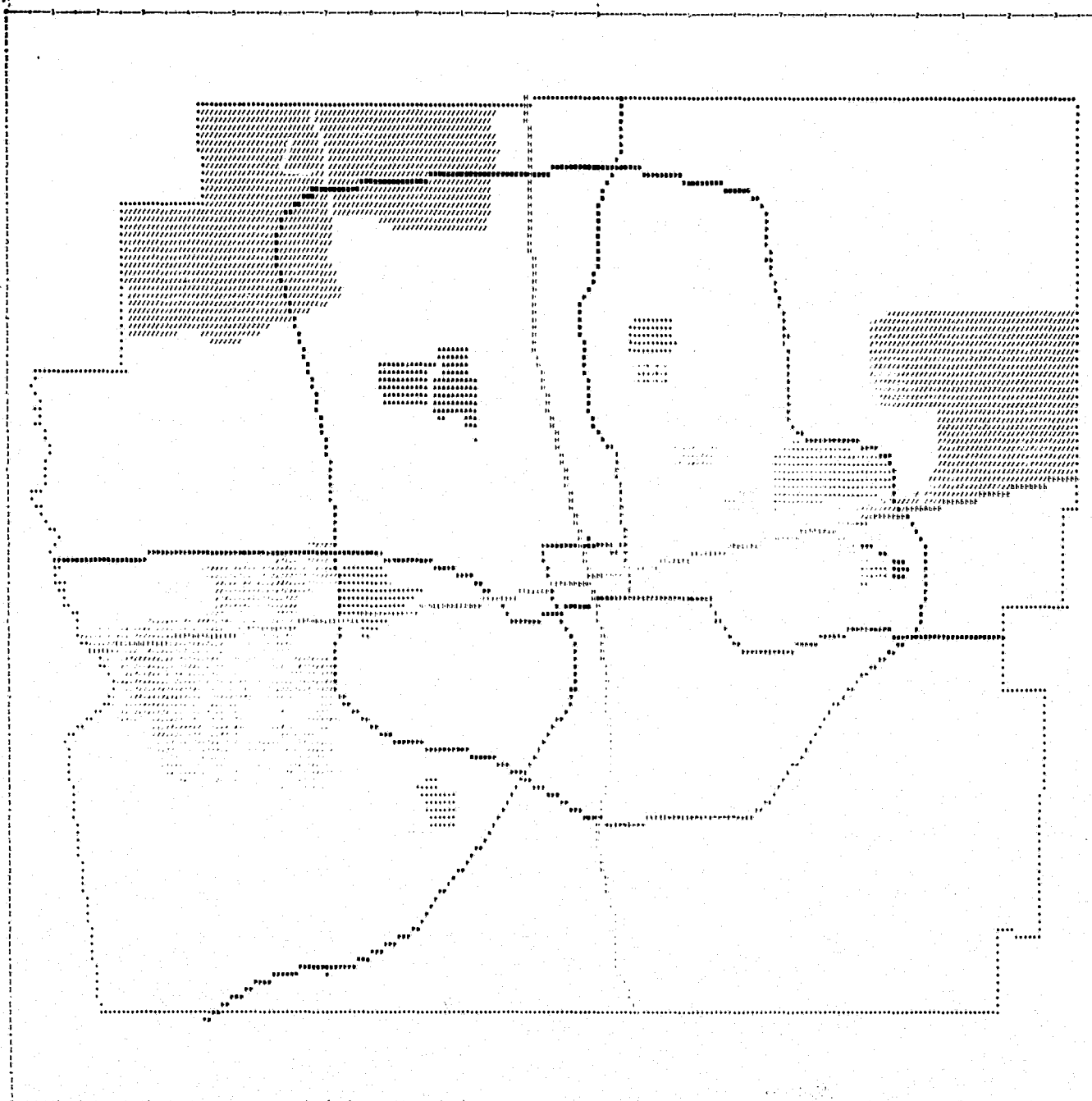
LEVEL	1	2	3	4	5	6
SYMBOLS	////////	#####	#####	#####	#####
FREQ.	1	1	11	4	2	190
MINIMUM	-70.00	-35.00	0.0	60.00	120.00	180.00
MAXIMUM	-35.00	0.0	60.00	120.00	180.00	200.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

12.46 12.46 22.22 22.22 22.22 7.41

FIGURE 25. COMPUTER MAP SHOWING CHANGE IN POPULATION DENSITY, FRANKLIN COUNTY, 1960-1970.

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FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7
SYMBOLS	////////	*****	*****	*****	*****	*****
	////////	*****	*****	*****	*****	*****
	////////	*****	*****	*****	*****	*****
	////////	*****	*****	*****	*****	*****
	////////	*****	*****	*****	*****	*****
FREQ.	1	4	2	3	2	191	1
MINIMUM	-13.00	-0.05	50.77	99.59	140.44	174.31	200.22
MAXIMUM	-0.05	50.77	99.59	140.44	174.31	200.22	240.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

4.74 16.41 17.08 14.46 12.41 9.49 21.90

FIGURE 26. COMPUTER MAP SHOWING CHANGE IN NUMBER OF HOUSING UNITS, FRANKLIN COUNTY, 1960-1970

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

split as they change in land use. It is possible to identify these cases and convert the 1960 configuration to 1970, but since the purpose is only to illustrate the application, this conversion was not done. These comparisons and resulting in-sights could be done in many ways using a variety of variables. The point is, standing alone or merged, the data generated from the Skylab imagery substantially increases the planners capability to complete the work required in the five application areas described previously.

The true value of this information can only be assessed in terms of its impact on decisions. Comparisons of the cost of obtaining it from the satellite with that of the present means can be used as a guide for gauging the operational utility of the data. Several different comparisons can be developed on the basis of different assumptions. As a starting point, the cost to the State of placing the interpreted Skylab data into a useable format and generating the map output would run approximately \$100.00 per county (1 man day at \$80.00 plus \$20.00 computer time). If the geographic base file does not exist for the county the cost increases by \$216.00. This would be a one time investment covering multiple uses. Additional data maps cost \$20.00 each. Thus, the Franklin County land use change, population density and housing unit maps cost \$140.00 to produce. This cost is fixed and no matter what the source of input data, Skylab or conventionally produced, they would apply. Skylab data does not significantly increase or decrease the State's in-house data processing costs. The cost of obtaining the raw data from alternative sources provides another basis for cost comparisons. Each of the presently used alternative sources have different acquisition costs.

Land use information obtained from the Skylab type data, as an operational augment to the Development Planning process, would provide a number of distinct benefits.

- . The change in land use could be routinely monitored across the entire State.
- . Annual update would be practical, and such frequency of the monitoring could be improved to an annual review. Timing would greatly enhance our program capability.
- . The overview change monitoring could become a fixed budget item with an in-house handling price tag of \$8,800 per year (88 counties X \$100/county).
- . The output could be routinely disseminated to local planning programs which would then be operating upon a uniform base.

In order for these operational benefits to be realized, there would need to be a systematic capability to process the Skylab data and deliver the final output. These benefits could be realized best if the processing system were established within the State and responsive to its requirements. Additionally, other levels of planning, i.e., regional and community require additional detail which could be placed within the general framework provided by Skylab data.

The Mid-Ohio Regional Planning Commission

From the regional perspective, the Mid-Ohio Regional Planning Commission has reviewed the changes in land use in Franklin County from 1962-1973 based on Skylab data and assessed its utility in the context of a regional planning process. The approach to this process was to give the information product to each of several types of regional planners. Thus, the assessment reflects the judgement of comprehensive and short-term planners.

Generally speaking the urban growth map is of most immediate use to comprehensive and projective planners where detail is of less importance. The short-term planners, such as transportation planners, have a real desire to obtain land use change data in the planning of mass transit requirements. The detail necessary by these planners is lacking in the Skylab type data.

Several divisions of the Mid-Ohio Regional Planning Commission could utilize the information. The major use would be in monitoring growth and its impact on the region. The information could be an effective tool in evaluating the effectiveness of both regional and local policies related to growth.

The information is sufficient to be useful, but a higher level of specificity is desirable. For example, the following would improve the map's utility:

- . availability at a scale of 1:36,000
- . illustration of smaller development packets in rural areas
- . identification of specific linear developments along thoroughfares and vacant land ready for development
- . provision of more detailed land use and density information
- . capability to print several types of maps.

Mid-Ohio currently is using this type of information to update land use maps of the region and the Geographic Base File so that the information can be used in conjunction with other computerized data.

Currently, to update a land use map for the county and obtain information such as employment, commercial and industrial floor area, automobiles, and population densities, the agency expends approximately \$30,000 annually. However, this activity includes much more information than is shown on the Skylab map. To monitor growth trends and evaluate policy impact this information is needed on an annual to biannual basis.

In conclusion, the map itself could prove to be a very useful tool in the management of growth and evaluation of policies from a regional perspective. If it is possible to obtain more detailed land use classifications to update land use maps, the value of the information would be increased substantially.

The City of Columbus

Locally, the City of Columbus has evaluated the Skylab land use change information from the perspective of the city planner. The information is relevant to understanding developing patterns of urbanization and population changes on a large scale. The maps utilized by the city planner are plot maps, annexation maps, capital improvement maps, and rezoning maps. The information in the Skylab map is of minimum use and is mainly a complementary form of data. If quantitative data in census tracts, such as acreage change in land use, could be obtained the map would be more useful. Larger scale and more land use categories are needed to improve the usefulness of the Skylab map for city planning.

If the information can be routinely updated, the information would be more meaningful. In addition, information for adjacent counties would be very useful since the city is not in a position to readily measure land use changes in them. If there were information that could show the interrelationship between land use and zoning decisions such information could be used in code enforcement. Updates should be annual or semi-annual.

To conclude the cities assessment, the information as it now stands appears to complement what is already known. It would be a helpful tool for presentation and display purposes, and could be more useful if the area coverage were expanded and the information regularly updated. As the information is now, the applicability is marginal.

The Franklin County Auditor

The Franklin County Auditor's appraisal covers only the urban growth map generated from Skylab photography in light of its potential usefulness in

the day-to-day work of the section. The information is relevant and helpful to a point but the information content of the map showing the change from agricultural to urban is not sufficient. To be useful, such a map would need to be detailed in the type of agricultural or urban land use. Property valuation requires a knowledge of crop types and soil types for the valuation of agricultural parcels. Similar detailed information is required for valuating urban land uses. The map, therefore, is not of value in its present form. If the map could be increased in detail of land use and be of larger scale so that specific parcels could be located, it would be of high value. A map of this detail would be required annually, but could be useful in looking at new construction semi-annually.

The current cost for obtaining and evaluating all data needed for implementing the new agricultural taxation law is not known because this is the first time through the process; however, the regional valuation process alone takes approximately one person year.

SUMMARY OF RESULTS
AND
MAJOR CONCLUSIONS

SUMMARY OF RESULTS AND MAJOR CONCLUSIONS

This program has involved the real-world testing of the potential usefulness of multispectral Skylab photography in three resource management applications in Ohio (i.e., timber, coal, and agriculture). The summary of significant results and applications offered below is based on a combination of research and user views generated during the course of this three-task study.

Research Results and Conclusions

Timber Task

Skylab type data (S190A, S190B) can be used for gross (large area) woodland inventories and mapping with little to no requirement for ground truth and aircraft data. Both conventional photointerpretation and machine-assisted procedures can be effectively utilized. In this case, the use of Skylab imagery for total area woodland (county) surveys was found to be more accurate and cheaper than conventional surveys using aerial photo-plot techniques.

Machine-aided (primarily density-slicing) analyses of Skylab 190A and 190B color and infrared color photography demonstrated the feasibility of using such data for differentiating major timber classes including pines, hardwoods, mixed, cut, and brushland providing such analyses are made at scales of 1:24,000 and larger. Detailed machine-analysis, reinforced by knowledgeable field personnel, indicate that sufficient spectral differences exist to make automatic machine (computerized) separation of pine and hardwood stands possible. Further differentiation of mixed hardwood and softwood types in Ohio study sites (which have small, extensively mixed forest stands) was not possible using available Skylab imagery. Sample demonstrations (verified by

aerial and in-field checking) indicated that density slicing of Skylab color and color IR film may be used to classify forest stand maturity into the following categories of commercial interest: mature timber, intermediate and pole timber, seedling/sapling stands, brushland and cut/cleared areas. Skylab 190A and 190B capabilities were inadequate to detect tree stress/damage conditions in northeast Ohio brought about by grapevine infestation.

Surface Mining Task

Manual and machine-assisted image analysis indicated that spectral and spatial capabilities of Skylab EREP photography are adequate to distinguish most parameters of current, coal surface mining concern associated with: (1) active mining, (2) orphan lands, (3) reclaimed lands, and (4) active reclamation. Excellent results were achieved when comparing Skylab and aerial photographic interpretations of detailed surface mining features. The major limitation is in the topography/slope area which requires stereo viewing capabilities not provided by Skylab. However, by viewing conjugate Skylab and aerial photographs at the same scale, stereo effects are produced, which when photogrammetrically calibrated, may be adequate for such use.

Urban Growth Agricultural Encroachment Task

Simple manual photointerpretation of Skylab photographs generate accurate maps and numerical data of the extent and direction of urban growth in relation to agricultural land. When combined with other data bases (e.g., census, agricultural land productivity, and transportation networks), a comprehensive, meaningful and integrated view of major elements involved in the urbanization/encroachment process is provided. Such a perspective can provide state, regional and local government agencies with a tool for planning and

developing a strategy for minimizing prime agricultural land depletion in the future. Based on the application procedure and enforcement requirements associated with Ohio's recently enacted law for assessing agricultural land for taxation in accordance with usage, the potential implications of using satellite data (such as Skylab) for periodic monitoring of agricultural land use and new construction over large areas could be significant. With few exceptions, that can be met by selective aerial surveys or on-site visits, repetitive Skylab data can meet most monitoring requirements.

Other

The use of the blueprint/blueline techniques for transferring Skylab data onto existing base maps appears to hold high promise for producing useful, accurate and inexpensive products that can be reproduced and disseminated to a wide user audience at commonly used scales. The 1" = 1 mile (1:63,360) scale tested in this program appeared to be a good compromise between feature detail and synoptic perspective of interest to users.

User Assessment Conclusions

Timber Task

Participating user groups involved in Ohio woodland management activities considered current Skylab type data and associated data products to be of marginal value only. However, if experimental findings relative to the potential of using Skylab data to differentiate major species and maturity classes can be translated into an operational program to provide such information for entire counties, the use and value of the Skylab data will increase dramatically. Existing computerized soil and vegetation data in Ohio could

possibly be correlated with available Skylab data to generate the required species information.

Surface Mining Task

The major user of remote sensing data for surface mining applications in Ohio, the Department of Natural Resources, indicates that the potential utility of Skylab data for current mining and reclamation monitoring has been satisfactorily demonstrated and that both satellite and aircraft data are being used in State mining and reclamation programs. Routine, operational use, however, will require development of a total automated system capable of merging various digital data bases including satellite data. Still needed is a detailed analysis of the potential of using remote sensing data (including Skylab data) for locating and evaluating unreclaimed land and monitoring restoration progress.

Urban Growth-Agricultural Encroachment Task

Participating State user personnel have concluded that, standing alone or merged, the data generated from Skylab imagery analysis can substantially increase the planners capability to complete existing requirements in programs involving: (1) allocation of funds to local planning agencies according to growth distribution and land use change, (2) assessment of economic and community development implications of land use changes in the Lake Erie Shore Zone (in response to Federal Coastal Zone Management Act), (3) preparation of a statewide land use and growth policy by 1977 (HUD), (4) development of a statewide economic development strategy (required by Economic Development Act), and (5) development of an Ohio Growth Allocation Model which simulates the changes in community land use patterns (such as agricultural land use) resulting from alternative policy decisions. Because of the shortcomings in existing

data sources, the State is considering operationally incorporating satellite Earth resources survey data into these programs. The Skylab effort, which involved reformatting (digitizing) results of Skylab urban growth interpretations and subsequent merger with other socio-economic data bases (e.g., census, housing units, and general land use) provided State planners with a preview of what can be expected in way of an output from routine satellite data use in the future. Technical and economic implications of operationally using such data were also provided.

Participating regional planners have concluded that the capacity to monitor urban growth and its impact on the region (demonstrated by the urban growth/agricultural encroachment map prepared from Skylab photography) could be of immediate use to comprehensive and projective planners in evaluating the effectiveness of both regional and local policies related to growth. If more detail could be provided from Skylab imagery on land use classifications of the type required by short-term planners, the value of this type of data would be increased substantially. City planners viewed these same products as being only complementary to existing information. Current usefulness would be mostly for presentation and display purposes. Results could, however, be more valuable if the area coverage and land use detail were expanded and information regularly updated.

Conclusions Concerning Use of Remote Sensing Data in the State of Ohio

As a result of participating in the Skylab program, some ideas as to the utilization of remote sensing in the State were developed and are set down in this section.

- . A description of the present institutional and technical capabilities of the State.

- . A discussion of the elements of a state mechanism.
- . A summary of the status and steps to be taken in improving or developing such a mechanism.
- . A discussion of how the mechanism would work to support state, regional and local government users.

Existing Capabilities

Presently the State of Ohio has diverse, special purpose remote sensing capabilities within several agencies.

- . The Ohio Department of Transportation (ODOT) has a section devoted to aerial photo interpretation. Their work is limited to highway engineering and they use primarily low level aircraft imagery.
- . The Ohio Department of Natural Resources (ODNR) has a library of aerial photographs, interpretive equipment and a small staff capability. Work focuses upon low level aircraft photography with some previous exposure to satellite imagery and computer processed information.
- . In addition over half of the regional organizations within the State have the qualified staff, in house, to make use of aircraft photography.

Each of these Departments has a different mission and therefore, pursue different applications, and varying types of remote sensing data. No formal overall institutional unit has been established for the purpose of coordinating data collection and utilization needs. Presently, they are coordinated at the staff level on an ad hoc basis.

Agency staff experts are augmented by a variety of technical tools either developed or under development by the State.

- . DNR has the Ohio Capability Analysis computer program already completed. These software programs provide a solid data handling/manipulation system as well as a resource analysis tool.
- . The Ohio Environmental Protection Agency has a current contract with the U.S. EPA for the development of a water quality model. When finished, this computer program will be able to store, retrieve and manipulate a variety of variables, including land use information developed from satellite computer compatible tapes (CCT's).

- . A centralized, machine processing system, which permits a variety of users to simultaneously and interactively analyze data developed from the satellites (LANDSAT, Skylab, etc.) or from an airborne scanner platform, such as used by a number of NASA centers.
- . A small technical staff to maintain the above system.
- . Capability to collect and obtain information from aerial photographic imagery.
- . A routine procedure for training state and local users in the use of remote sensing techniques in general.
- . A routine library function which keeps accurate, up-to-date listings of all the remote sensing data acquired within the state.
- . An equitable fee schedule which spreads the cost of these data collection and processing systems, training sessions and library functions across the various users.

Developmental Status

The elements of the required mechanism for using remote sensing described above are certainly within reach of the State. Specifically, a number of initial steps are being taken by ODECD toward putting each of these elements in place. The steps include:

- . Machine Processing System. The state has looked at the systems developed by NASA for Mississippi and Larsys and will be gaining practical exposure to the Bendix MDAS system. Our initial step in actually acquiring the in-house capacity to process satellite data is for ODECD to work with JSC on placing a water algorithm* on the State's IBM 370/145 computer system. The OEPA and ODNR, along with other users, will be given the opportunity to directly access the computer program as their needs require. The water program should serve as a feasibility test of the development of an in-house machine processing system.
- . Handling Airborne Scanner Data. To date, our interaction with a wide variety of users has indicated a distinct need for higher resolution data which can be handled with a machine processing system. Thus, the ability to interpret

* Earth Resources Procedure Manual for the Detection and Location of Surface Water using ERTS-1 multispectral scanner data, JSC 08454, Revision A, 1973.

large amounts of data very quickly and the ability to format, store, and retrieve it in a computer system are capabilities which state and local users find highly desirable. An airborne scanner could fill this need while simultaneously fitting into the synoptic overview provided by satellites such as LANDSAT.

- . In-house Technical Personnel. If the machine processing system is to be effectively used, the State must have the in-house capacity to maintain, improve and expand it. To date, there are at least two qualified scientific programmers who could be partially assigned to the system. Budget constraints would make it very difficult to expand this staff without outside support.

Operation of Required Mechanism

The implementation of the required mechanism will be incremental. Certain selected information products having high user interest would be initially established to: (1) develop the day-to-day knowledge of an operational remote sensing system, and (2) develop a user group directly involved in routine use of remote sensing.

As the user sophistication and interest in remote sensing data expands, more capability and information products will be added where appropriate.

Response to User Needs. By the developing of an in-house capability for processing satellite and airborne multispectral scanner data, the system will be able to meet the varying resolution requirements of the users the state may serve. At the same time, the system can provide information to a wide variety of user applications, i.e., developmental, environmental and resource, in both the planning and program settings. And finally, by using a centralized processing system with interactive terminals, the users may expect efficient delivery of information output that can be linked to individualized systems or procedures.

Potential Applications. Precise definition of the extent or scope of applications is not possible at this time; however, the largest user groups

- . The Ohio Department of Economic and Community Development is currently working on a prototype Spatial Allocation Model. The resulting computer programs will be used in the evaluation of alternative growth policies for the State. It will also have the capacity to handle data developed from a variety of remote sensing sources.

This mixture of staff and technical resources forms the present environment for using remote sensing in the State of Ohio. In short each unit has its own staff and its own system for handling remote sensing data. In addition, the technical resources of many capable consultants in the State may be drawn upon as necessary. This diverse staff and facilities interact in different ways and in different configurations based upon overlapping needs and the opportunities at hand. As an example, DNR, EPA, DECD and NASA are jointly funding and technically supporting the development of a systematic statewide land use inventory from LANDSAT CCTs. This cooperative project resulted from an overlapping need within the three Departments for a generalized inventory of the entire state which could be routinely merged into their existing or potential computer software programs.

Date Utilization Mechanism

The response to user awareness/interest efforts, the already available staff and technical resources and the use of state financial resources in using LANDSAT CCTs point to the fact that the potential for making routine use of remote sensing data derived from a variety of sources including satellites is very high in Ohio. There is one missing ingredient which is a reliable and efficient mechanism for interfacing the variety of users, their applications and the data provided by various types of remote sensing. In Ohio, such a mechanism requires the following key elements.

for this system are the three state agencies, OEPA, ODNR, and ODECD. The fifteen (15) regional planning organizations in Ohio have also shown interest in and demonstrated the use of remote sensing data in their on-going functions. The key point here is that a hands on system with in-house maintenance support can provide the flexibility to meet these applications.

Techniques and Facilities. Techniques will vary to some extent depending upon the application due to some advantages of special purpose automatic processing algorithms used operationally or other interpretive technique; however, automatic pattern classification computer programs will be emphasized where possible with tables, maps, and plots generated routinely. The facilities should be lodged in the now existing State Data Center where computer environment considerations are met. A plotter should be centralized with output delivered via interdepartmental or government mail.

Data Acquisition. It is proposed that a revolving library of tapes be established through the EROS Data Center where satellite data over Ohio can be automatically obtained for the price of handling and returned after extraction of desired data. This method would provide timely acquisition of desired data only to support the routine needs of the users.

Processing. Initially, algorithms would be processed on a general purpose computer; however, at some point a combination of general purpose and a special purpose minicomputer system such as used in the Mississippi program could be used. All products from the system should be reproducible and a catalog maintained of developed products would be kept in the State's Library System. Finally, a rotary funding system for charging for the dissemination and reproduction of products is needed.

Conclusions Relevant to Future NASA Programs

The indepth analysis of Skylab 190A and 190B photographic data for forestry, coal surface mining, and urban-agricultural encroachment applications and the subsequent evaluation of results by representative user groups in the State of Ohio have made possible the following observations of potential significance to future NASA programs.

Data Use Value

- The advantage of Skylab EREP photography most appreciated by program participants was the comprehensive coverage provided for such large areas with a single uniformly exposed photographic image in color, color IR and black and white formates. Similar conventional aircraft coverage require the generation of hundreds to thousands of photographs which may vary in orientation and/or illumination.
- The cost savings made possible by obtaining photographic coverage from satellites as compared to expensive aircraft coverage was also frequently noted. To obtain such photography requires procuring the services of an aerial photo survey agency or maintaining a photographic aircraft, both of which can be an expensive proposition if repetitive surveys of large areas (counties or larger) are involved. This aspect is most appreciated by the planner/user who does not require the detail recorded in typical large- to medium-scale aircraft imagery.
- The potential for conjugate aircraft-satellite stereo viewing, although not evaluated in detail, appears to hold promise of producing significant cost savings by reducing the conventional 50-60% aerial photographic overlap requirement to as little as 10%.

Data Use Limitations

- The major current use limitation is the fact that such data are not routinely available.
- While some State planners have requirements for generalized data, most users in local governmental units perceive resolution needs of .5-2 meters, i.e., at least one magnitude better than current S190B terrain camera data. This factor accounted for most of the marginal Skylab data use assessments made by participating end-users. Thus, the single greatest deterrent to the use of Skylab type imagery is probably the fact that it currently requires highly-trained specialists using sophisticated equipment to tell the user what he does not readily recognize himself. However, if user awareness of the technology can be improved and satellite data capabilities (resolution and stereo) were to approach those of high-altitude aircraft, then broad acceptance by a wide user community can be immediately expected. The usefulness of current Skylab data capabilities can be increased in certain applications by providing more seasonal data acquisition flexibility.
- Skylab 190B imagery used in this study contained density variations which would require photographic or computerized correction to be utilized effectively in applications involving spectral analysis techniques over large geographic areas.
- In this study, the two black and white IR S190A channels were mostly redundant and either channel would have been sufficient. Further, useful information content in the Skylab 190A near IR channels was found to be less than that contained in the IR LANDSAT scanner channel which covers the spectral region out to 1.1 micrometers.

Operational Data Use Implications

- Current use of Skylab EREP type photography and correlations with aircraft imagery and other data bases are limited to manual and photo-electronic processing techniques. If selected

photographic items could be made available to interested users in a digitized format and at a nominal cost, they could be effectively incorporated into a variety of on-going modelling and/or computer resource inventory programs.

- For smaller governmental units, frequent changes in priorities, problems, and staff combined with limited resources will continue to delay the routine use of Earth resources satellite data. Therefore, the establishment of additional federal application centers or federally-funded application centers having responsibilities for serving localized users could be effective at moving forward toward operational applications.

APPENDIX

APPENDIX A

TABLE A-1. COVERAGE AND QUALITY OF SKYLAB S190A PHOTOGRAPHY OF OHIO

Date	Frame	Area	Quality Comments*
SL-2			
6/12/73	152	Eastern Michigan, Detroit, Lake St. Clair, Western Lake Erie	Fair
6/12/73	153	Detroit, Toledo, Sandusky Bay, Western Lake Erie	Fair
6/12/73	154	Toledo to east of Cleveland	Fair
6/12/73	155	Sandusky Bay to Erie, Pa.	Fair
6/12/73	156	Cleveland area	Fair
6/12/73	157	Eastern Central Pennsylvania	Poor
SL-3			
8/5/73	185	Eastern Michigan, Detroit, Lake St. Clair, Western Lake Erie	Excellent
8/5/73	186	Detroit, Toledo, Sandusky Bay, Western Lake Erie	Excellent
** 8/5/73	187	Sandusky Bay to Erie, Pa.	Excellent
** 8/5/73	188	Cleveland and Northeastern Ohio	Excellent
** 8/5/73	189	Eastern Ohio, Western Pennsylvania	Excellent
** 8/5/73	190	Eastern Ohio, Western Pennsylvania, Pittsburgh	Excellent
8/9/73	017	Northern Indiana, Southern Michigan, and Western Ohio	Very Good
** 8/9/73	018	Western Ohio	Very Good
** 8/9/73	019	Central Ohio	Fair
** 8/9/73	020	Eastern Ohio	Fair
** 8/9/73	021	Eastern Ohio, Western Pennsylvania, and West Virginia	Good
8/9/73	022	Eastern Ohio, Western Pennsylvania, and West Virginia	Excellent
8/9/73	023	West Virginia	Very Good
8/9/73	024	West Virginia, Virginia	Good
9/15/73	307	Indiana/Kentucky	Good
9/15/73	308	Central Kentucky/Indiana	Very Good
** 9/15/73	309	Southwestern Ohio	Very Good
** 9/15/73	310	Columbus & Southeastern Ohio	Good
** 9/15/73	311	Eastern Ohio/Western Pennsylvania	Fair
9/15/73	312	Western Pennsylvania	Good
SL-4			
1/25/74	013	Michigan, Indiana, and NW Ohio	Excellent
1/25/74	014	Indiana, and NW Ohio	Excellent
1/25/74	015	Western Ohio	Very Good
** 1/25/74	016	Western and Central Ohio	Good
** 1/25/74	017	Central Ohio	Good
** 1/25/74	018	Eastern Ohio	Good
1/25/74	019	Southeastern Ohio/West Virginia	Very Good
1/25/74	020	Southeastern Ohio/West Virginia	Fair

* Quality relates to general cloud cover condition over area covered by satellite photography. (Excellent: <5%, Very Good: 5-10%, Good: 10-25%, Fair: 25-75%, Poor: >75%)

** Major Skylab data source for current study.

TABLE A-2. COVERAGE AND QUALITY OF SKYLAB S190B PHOTOGRAPHY OF OHIO

Date	Type	Frame	Area	Quality Comments*
8/5/73	H.R. Color	SL3-83-153	Lake St. Clair & Ontario, Canada	Excellent
8/5/73	H.R. Color	SL3-83-154	Cleveland, Lake Erie, and Canada	Excellent
** 8/5/73	H.R. Color	SL3-83-155	Cleveland	Excellent
** 8/5/73	H.R. Color	SL3-83-156	Cleveland & NE Ohio	Excellent
** 8/5/73	H.R. Color	SL3-83-157	NE Ohio & Western Pennsylvania	Excellent
** 8/5/73	H.R. Color	SL3-83-158	Eastern Ohio, West Virginia, and Western Pennsylvania	Excellent
9/15/73	IR Color	SL3-87-052	Kentucky/SW Ohio	Excellent
** 9/15/73	IR Color	SL3-87-053	Columbus & Southern Ohio	Excellent
** 9/15/73	IR Color	SL3-87-054	Columbus & Southeastern Ohio	Good
9/15/73	IR Color	SL3-87-055	Eastern Ohio	Poor
9/15/73	IR Color	SL3-87-056	Eastern Ohio/Western Pa.	Poor

* Quality relates to general cloud cover condition over area covered by satellite photography. (Excellent: <5%, Very Good: 5-10%, Good: 10-25%, Fair: 25-75%, Poor: >75%)

** Major Skylab data source for current study.

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